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11.—Hakea rubriflora (Proteaceae), a new species from Western Australia

by Byron Lamont*

Manuscript received and accepted 21 March 1972

Abstract

A new species of *Hakea*, *H. rubriflora*, is described. This species has affinities with *H. pritzelii* and *H. prostrata* but the inflorescence and floral morphology of *H. rubriflora* are quite distinct. *H. rubriflora* is widespread in the Stirling-Eyre District of Western Australia.

Introduction

Plants of a previously undescribed species were included in a study by the author of the root systems of *Hakea* species in south western Australia. This species was first collected by Gardner and Blackall in 1928, but these specimens, as well as those collected subsequently, were regarded as a form of *H. prostrata* R.Br. All material collected by the author, together with that already held at the Western Australian Herbarium (PERTH) and the University of Western Australia (UWA), conforms to the description given here. The description is based on specimens from the type population on the northern sandplain bounding the Stirling Range.

Hakea rubriflora Lamont, sp. nov.

Section *Hakea;* Series *Glabriflorae* (after Bentham, 1870).

Frutex 2-3 m altus. Ramuli divaricati, flexuosi, irregulati obtusanguli, flavidi vel rubri. Cortex laevis. Ramuli et folia juvenes trichomatibus brevibus appressis. Folia elliptica (3:1) vel obovata (6:5), apice rotundata vel acuta, basi decurrentia cuneata vel cordata, 2-5 cm longa, 1-3 cm lata; margines dentatae, rarius denticulatae vel integrae, sclerenchymatae. Florae ternae aggregatae in axillaribus annotinis, duae ad folium accendentes, tertia ad caulem, foetidae. Squamae ad infimum pedunculi pusil lae et paucae, caducae. Torus rectus. Pedunculi 1 mm, glabri. Pedicelli 4-7 mm, glabri. Tubus perianthii sub limbo revolutus, ad flexum 0.9-1.4 mm. Segmenta perianthii ad maturitatem secedentes et e pedicello 20-30° sursum flexi, abaxialiter vitellini, adaxialiter rutilantes, margines atrosanguineae. Limbi segmentium superorum reflexi, inferorum lateriflexi, in senectute torti, parum concavi, cremei tandem atrosanguinei. Nectarium truncatum, latissime 1.2 mm, depressione rubrotincta. Loculi antherorum linearis paralleli, connectivo procurrente. Pistillum e pedicello 30-40° deorsum flexum. Stripes obturbinatus, sulco perspicuo longitudinale per ovarium et stylum currente, 1.6 mm latus. Stylus crociaeformis, filiformis, perianthium breviter excedens, 1.1-1.7 cm latus, versus ovarium ruber rosae. Praebitor pollinis obconeus rectus; discus parum convexi. Fructus ovatus (2.4-3.1), apice late acute, margine adaxiale quam abaxiale rotundiore, 2-3 cm longa, 0.8-1.2 cm lata, 0.8 cm crassitudo, pagina rugosa; appendices non nisi suturarum margine vel carentes, 0.5-1.5 cm longa. Semen apice asymmetrice acutum, basi rotundatum, 1.7-2.2 cm longum; nucleus 6-8 mm; ala in margine supera leviter decurrens, 1.1-1.4 cm longa.

Divaricate shrub, 2-3 m tall. Branchlets flexuose, irregularly obtuse-angled, yellow to red. Bark smooth. Trichomes short appressed on young stems and leaves. Leaves elliptic (3:1) to obovate (6:5), apex rotund to acute, base decurrent, cuneate to cordate, margins dentate, rarely denticulate or entire, sclerenchymatous, length 2.5 cm, breadth 1-3 cm. Inflorescence an axillary cluster of three flowers, two towards the leaf, the other towards stem; borne on previous season's branchlets. Flowers with foetid odour. Scales at base of peduncle small and few, caducous. Torus straight. Peduncle 1 mm, glabrous. Pedicels 4-7 mm, glabrous. Perianth tube revolute under the limb, 0.9-1.4 cm to summit. Perianth segments linear, separating as they mature to recline upwards 20-30° from axis of pedicel, abaxial surface dull yellow, adaxial surface orange-red, margins red-black. Limb of upper segments reflexed, and of lower segments recurved, twisting during senescence, slightly concave, cream becoming red-black. Nectary truncate, 1.2 mm at widest diameter, concavity tinged red. Pollen sacs linear and parallel, with connective slightly exceeding anther. Pistil reclined downwards 30-40° from axis of pedicel. Stipe obturbinate, with distinct longitudinal groove which may continue through ovary and style, 1.6 mm long. Style crozier-like, filiform, slightly exceeding perianth, length 1.1-1.7 cm, increasingly rose-red towards ovary. Pollen presenter obconical, straight; disc slightly convex. Fruit ovate (2.4-3:1), apex broadly acute, adaxial margin more rounded than abaxial, length 2-3 cm, breadth 0.8-1.2 cm, width 0.8 cm, surface wrinkled, appendages, if present, restricted to edge of sutures, length 0.5-2 mm; apex of seed asymmetrically acute, base rounded, length 1.7-2.2 cm; nucleus 6-8 mm; wing slightly decurrent along upper margin, length 1.1-1.4 cm.

Herbarium Material

Holotype: 28 miles east of Cranbrook, north Stirling Range. 21 Oct. 1971, Lamont 1034 (UWA).

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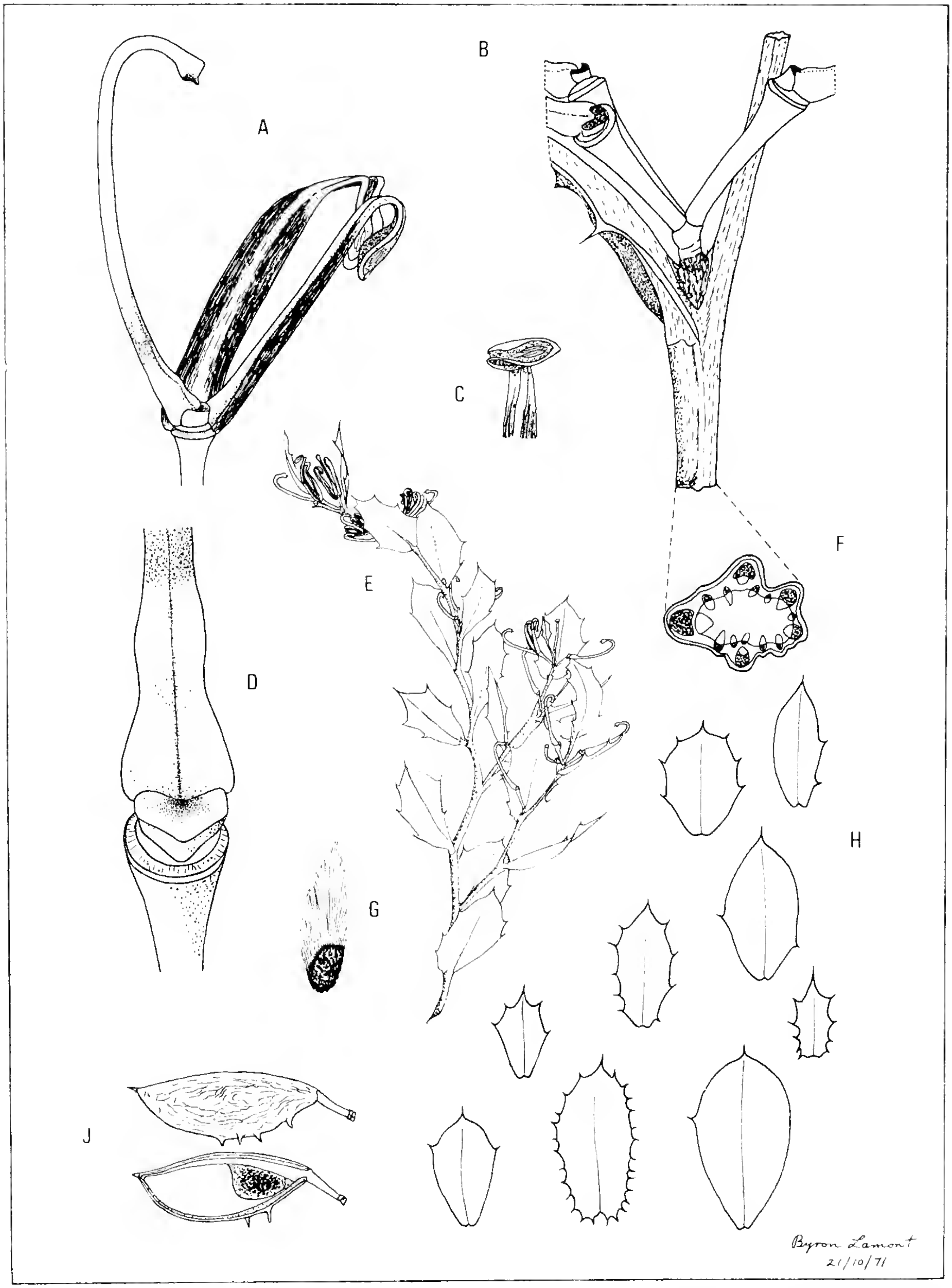

Figure 1.—*Hakea rubriflora* Lamont, sp. nov. A, — half-flower, x 4.5; B, — inflorescence in relation to axis, x 4.5; C, — limb of old perianth segment, x 4.5; D, — ovary, stipe, nectary, torus, adaxial view, x 14; E, — flowering branch, x 0.5; F, — stem, transverse section, x 14; G, — seed, x 0.9; H, sample of leaf shapes, x 0.6; J, — follicle, x 0.9

Isotypes: These have been deposited at the following herbaria: K (2 sheets), PERTH (2 sheets), UWA (2 sheets), AD (2 sheets), MEL (2 sheets).

Other specimens: NE Kalgan R., S Stirling Rd, Aug., *George* 188; near Porongorup Range, *Steenbohm;* Chillinup, E Stirling Range, Oct., 1928, *Gardner* 2161; Chillinup, E Stirling Range, Oct., 1928, *Gardner and Blackall;* Cheyne Bay turnoff, Hassell Hwy, Oct., *Lamont and Newby;* (PERTH). 43 ml peg, Chester Pass, Stirling Range, Oct., *Lamont;* 5 ml S Chillinup Pool, Pallinup R., Oct., *Lamont and Newbey;* 1 ml NW Boat Harbour, Cheyne Bay, Oct., *Lamont and Newby;* (PERTH and UWA). N Kalgan R., Albany-Borden Rd, Aug., *Brittan;* S Stirling Rd, Aug., *Baird;* junction S Stirling Rd and Albany-Borden Rd, Aug., botany students; Bremer Bay, *Speck;* Arboretum, Ongerup, Oct., *Lamont and Newbey;* (UWA).

Discussion

As their fruits are similar, *Hakea rubriflora* is most likely to be confused with *H. pritzelii* and red-flowered forms of *H. prostrata* (see Fig. 1). However, the orange-red perianth segments with red-black margins of *H. rubriflora,* from which its name is derived, are quite distinct. In addition, the species has a three-flowered inflorescence, not 8 to 20 per cluster as in *H. pritzelii* and *H. prostrata;* the pollen presenter is straight, not oblique; the stipe is obturbinate, not cylindrical; the leaves are decurrent, not auriculate and the base of the seed in *H. rubriflora* is unevenly rounded, not acute as in *H. pritzelii* and *H. prostrata.* At the young seedling stage *H. rubriflora* may be determined by the large number of marginal teeth (10-20 per cm) with 1 mm and 0.5 mm long teeth generally alternating, the obtuse-angled stem and appressed trichomes. Young seedlings of *H. pritzelii* and *H. prostrata* have less than 10 uniform teeth per cm of leaf margin, the stem is evenly rounded and the trichomes are erect.

Hakea rubriflora is endemic to the South-West Botanical Province (after Diels and Pritzel 1905). The species covers a triangular area, the northern boundary extending from north-west of the Stirling Range to at least Esperance (250 miles), and the south-east boundary corresponding with the coastline east of Two Peoples Bay. *H. rubriflora* is restricted to the sandplains where it occurs on soils which range from dry, deep fine sands to seasonally-waterlogged clay-gravel. It is usually codominant with other proteaceous scrub species (after Specht 1970) of similar size. Individual plants flower for little more than two to three weeks during the period August to October. Because of the shrub's foetid odour when in flower it is known locally as the stinking Hakea.

Acknowledgements

Thanks are extended to Dr. N. M. Pritchard, visiting lecturer in the Botany Department, University of Western Australia, from the University of Aberdeen, Scotland, and to Mr. A. S. George of the Western Australian Herbarium for their assistance with the manuscript. This work was carried out during tenure of a Commonwealth Post-graduate Research Award in the Botany Department, University of Western Australia.

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12.—The Mygalomorph spider genus Stanwellia Rainbow & Pulleine (Dipluridae) and its relationship to Aname Koch and certain other diplurine genera

by Barbara York Main*

Manuscript received 19 October 1971; accepted 20 June, 1972

Abstract

The genus *Stanwellia* Rainbow and Pulleine is redefined and distinguished from other Australian diplurine spiders. Four already named species are attributed in the genus, two new species described and several unnamed populations are discussed. Significance of the biology and distribution of the genus and its New Zealand affinities are mentioned. The genus *Aname* Koch is discussed and the systematic position of species hitherto included in this genus reassessed.

Introduction

The genus *Stanwellia*, although common and widely distributed in South Eastern Australia, has received little mention in the literature records of Australian Mygalomorphae. This is due in part to its confusion with the poorly defined genus *Aname* Koch. *Aname* has provided the dumping ground for numerous diplurine species, many of which properly belong in other genera (see Table 1).

The uncertainty of generic placement of many Australian diplurines is because of the sexual dimorphism of adults, a feature common to all Mygalomorphae. The palp and modifications of the anterior legs of mature male Mygalomorphs have customarily been used in diagnoses of genera and species. However the bulk of Mygalomorphs in museum collections consist of haphazardly or randomly collected specimens. Thus many earlier systematists have had little evidence on which to associate males and females. This has often resulted in species being attributed to the wrong genus and occasionally an incorrect specific association of a male and female. The author has been able to determine the correct relationship of males and females of many species and thereafter to establish generic distinctions, by the following methods. Immature males have been collected from burrows found in aggregates of specimens of which the identity of the females is known. These immature males, recognizable as such by the slightly swollen palpal tarsi, have then been reared to maturity in flower pots of soil. Secondly, pit-traps into which wandering males fall, have been set down in sites where females of known species have been observed. Thirdly, wandering males have sometimes been fortuitiously collected 'on location'. Search has then revealed conspecific females in their burrows.

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Table 1

Species originally attributed to Aname *Koch and their revised generic positions*

Species		Revised generic position
♀ *Aname arborea* Hogg 1901	=	*Stanwellia grisea* (Hogg 1901)
♀ *Aname bicolor* Rainbow 1914	=	*Atrax bicolor* (Rainbow 1914) (*)
♀ *Aname armigera* Rainb. & Pull. 1918	=	*Dekana armigera* (Rainb. & Pull. 1918) or (?) *Aname armigera*
♀ *Aname aurea* Rainb. & Pull. 1918	=	*Dekana* sp. prob. *grandis*?
♀ *Aname butleri* Rainb. & Pull. 1918	=	*Stanwellia grisea* (Hogg 1901)
♀ *Aname coenosa* Rainb. & Pull. 1918	=	*Aname coenosa* Rainb. & Pull. 1918 or *Dekana* sp.
♀ *Aname comosa* Rainb. & Pull. 1918	=	*Dekana diversicolor* Hogg 1901 (?)
♀ *Aname confusa* Rainb. & Pull. 1918	=	*Stanwellia nebulosa* Rainb. & Pull. 1918
♀ *Aname decora* Rainb. & Pull. 1918	=	*Stanwellia hoggi* (Rainbow 1914)
♂ *Aname flavomaculata* Rainb. & Pull. 1918	=	*Ixamatus flavomaculatus* (Rainb. & Pull. 1918)
♀ *Aname fuscocincta* Rainb. & Pull. 1918	=	*Ixamatus fuscocinctus* (Rainb. & Pull. 1918)
♀ *Aname grandis* Rainb. & Pull. 1918	=	*Dekana grandis* (Rainb. & Pull. 1918)
♀ *Aname grisea* Hogg 1901	=	*Stanwellia grisea* (Hogg 1901)
♀ *Aname hirsuta* Rainb. & Pull. 1918	=	*Dekana diversicolor* Hogg 1901 (?)
♀ *Aname intricata* Rainb. & Pull. 1918	=	*Chenistonia intricata* (Rainb. & Pull. 1918)
♀ *Aname maculata* Rainb. & Pull. 1918	=	*Chenistonia tepperi* Hogg 1901
♀ *Aname minor* Kulcz 1908	=	? *Ixamatus*
♀, ♂ *Aname nebulosa* Rainb. & Pull. 1918	=	*Stanwellia nebulosa* (Rainb. & Pull. 1918)
♀ *Aname pallida* Koch 1873	=	*Aname pallida* Koch 1873
♀ *Aname pellucida* Hogg 1901	=	*Stanwellia grisea* (Hogg 1901)
♀, ♂ *Aname pexa* Hickman 1929	=	*Stanwellia pexa* (Hickman 1929)
♂ *Aname pulchra* Rainb. & Pull. 1918	=	*Dyarcyops pulchellus* (Rainb. & Pull. 1918) (†)
♀ *Aname robusta* Rainb. & Pull. 1918	=	*Dekana grandis* (Rainb. & Pull. 1918)
♀ *Aname tasmanica* Hogg 1902	=	*Aname tasmanica* Hogg 1902
♀ *Aname villosa* Rainb. & Pull. 1918	=	*Aname villosa* Rainb. & Pull. 1918
♀ *Aname platypus* (L. Koch in Ausserer 1875) (‡)	=	?

Note: The types of all the above species (except *Brachythele platypus* Koch, *Aname bicolor* Rainbow and *Aname pexa* Hickman) have been seen by the authcr.

(*) Synonymy noted by Rainbow (1918) and Hickman (1964)

(†) New combination; originally described as *Arbanitis pulchellus* Rainbow and Pulleine 1918

(‡) Originally described as *Brachythele platypus* L. Koch in Ausserer 1875

Along with deliberate attempts to establish male/female associations of species on biological grounds, all extant types of Australian Mygalomorphae have been traced and most of these have been examined by the author. As a result it has been possible to make valid groupings of species into genera, which may now be more clearly defined.

Taxonomy of Diplurinae

The main purpose of the present paper is to discuss *Stanwellia* as distinct from other diplurine genera. Diplurine spiders are distinguished from the other sub-families of the Dipluridae by having two pairs of spinnerets and the paired tarsal claws bipectinate. They are generally large, dark coloured spiders and live in burrows in the ground or sometimes in silk tubes in rotten logs or moss and friable bark on the boles of trees. The following genera have been recorded from Australia: *Chenistonia, Dekana, Ixamatus, Aname, Stanwellia, Kiama* and *Sungenia*. The genus *Troglodiplura* described from the dried fragments of a single specimen found in a Nullarbor cave is possibly a 'fossil' genus. The present author tentatively regards *Sungenia* as a synonym of *Chenistonia*.

Status of the genus Aname

The holotype of *Aname pallida* Koch, which is the type species of *Aname* Koch, is lodged in the Hamburg Museum, Germany (sighted by the author in 1958). It was obviously a freshly moulted specimen when collected, hence the unpigmented or "pale" colour.

ANAME Koch 1873

Aname Koch, 1873. Die Arachniden Australiens, p. 465. Type species by original designation *A. pallida* Koch, 1873. ibid. p. 465-7. Pl. xxxv, F.8 Type locality: Bowen, Queensland. Collector probably Amelia Dietrich.

Description of holotype of Aname pallida

Although badly macerated the following features were recognisible:

Carapace length 6.5 mm; procurved fovea; eyes on a pronounced tubercle set back from margin and anterior row distinctly procurved (fig. 1); sternum badly distorted, posterior sigilla away from margin, misshapen but broadly oval (fig. 2). Labium broad, anteriorly indented and without cuspules or spines; cuspules on maxillae; chelicerae with teeth on promargin of furrow only, no apical teeth (i.e. no pseudo-rastellum). The palpal tarsus was swollen indicating that the specimen was an immature male; a pair of basal spines. Scopula present on palpal tarsus, and tarsi and metatarsi of legs I and II, a few scopulate hairs on tarsi III and IV. *Spines.* Tarsi of all legs without spines. I, Metatarsus ventral spines; Tibia ventral bristles. II, Metatarsus ventral spines; Tibia ventral spines and bristles. III, Metatarsus with spines on all faces; Tibia ventral and dorsal spines. IV Metatarsus with spines on all faces; Tibia ventral bristles and dorso-retrolateral spines; all femurs with dorsal bristles. Paired tarsal claws bipectinate. Abdomen macerated but appeared dorsally to have been of uniform colour.

From the above, a diagnosis of the genus *Aname* can be made as follows:

Carapace with procurved fovea; eyes on pronounced tubercle; labium broad and anteriorly indented, without cuspules; cheliceral furrow with teeth on promargin only; no pseudo-rastellum; posterior sternal sigilla away from margin (possibly variable); a proximal pair of ventral spines on palp tarsus; no spines on tarsi of legs; scopula on tarsi of palp and at least tarsi I and II.

Relationship of Aname *to other diplurine genera*

Thus *Aname* on the above characters can be distinguished from *Chenistonia,* which has a straight fovea and long narrow posterior sternal sigilla (F. 3) and possibly from *Dekana,* which although usually with a procurved fovea has narrow elongate posterior sternal sigilla. It has been observed that specimens attributable on morphology (not considering the doubtful feature of sternal sigilla) to either *Dekana* or *Aname* can be distinguished in life by the type of burrow constructed. *Dekana* specimens (males and females) build a forked (wish-bone or Y-shaped) burrow with only one arm of the fork opening completely on the surface; specimens which build a simple, unbranched burrow have been attributed to *Aname.* Both groups are widely distributed throughout Australia. *Dekana* has probably been derived from *Aname.* However, in the absence of an authentic male, the features listed above, alone, would not unequivocally distinguish *Aname* from *Ixamatus,* the type locality of whose type species is also allegedly Bowen, Queensland. The male of *Ixamatus* has no tibial spur on the first leg, *Chenistonia* and *Dekana* have a spur (fig. 4). The female of *Stanwellia* differs from *Aname,* and all other known Australian diplurines, by having no spines on the palp tarsus (figs. 7, 7a).

Since at least nineteen of the subsequently described twenty-five species of *Aname* can readily be attributed to various other named and more clearly defined genera (although of later erection) the genus *Aname* itself is thus reduced in size (see Table 1). The rationale for transferring the various species of *Aname* to other genera (see Table I) will be discussed along with the appropriate genus (Main in preparation).

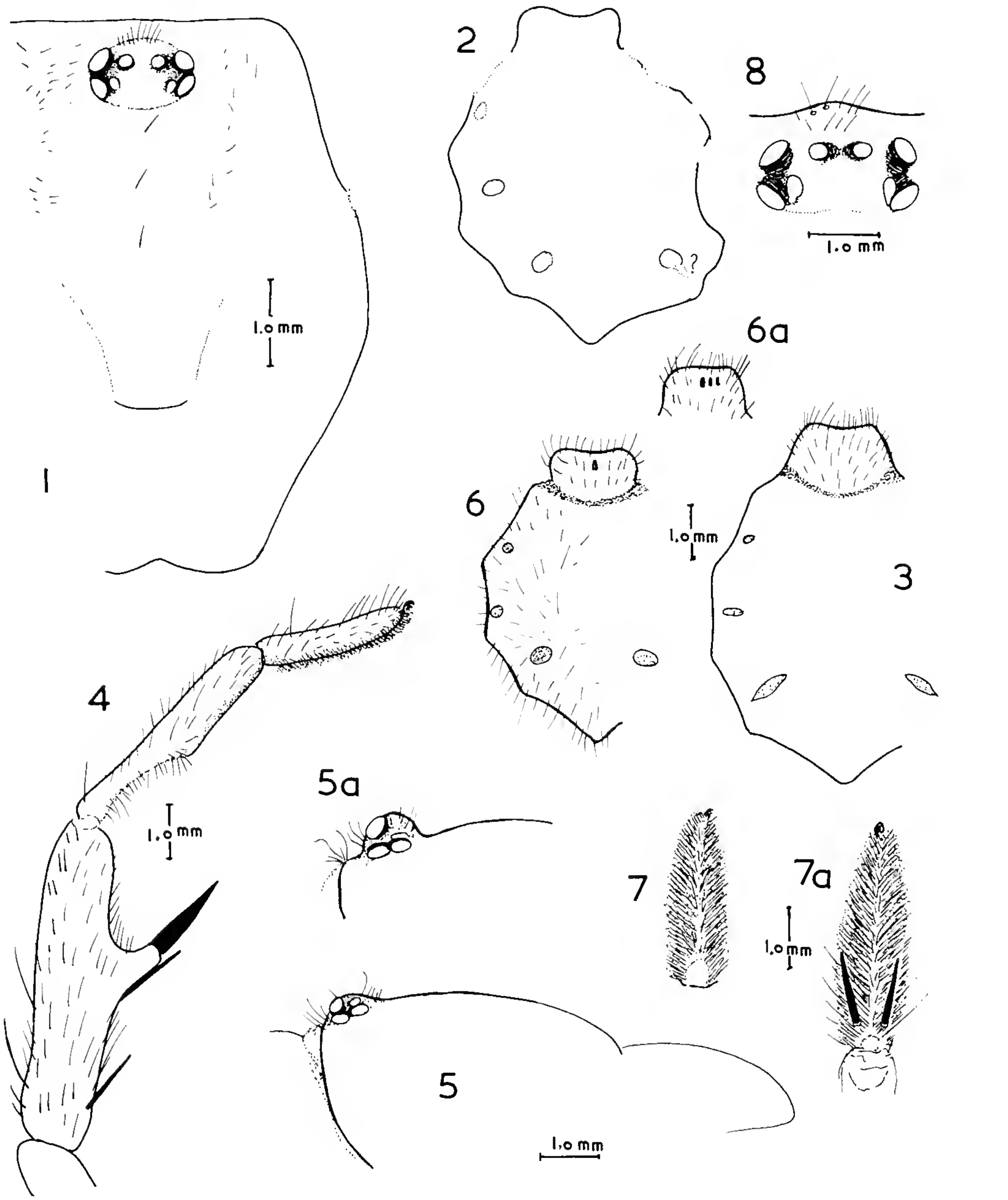
By inference, species in eastern Australia (with the exception of certain undescribed forms which do not have leg scopula on the females) which do not by definition fall into *Dekana, Chenistonia, Ixamatus* or *Stanwellia,* might well be left in *Aname* or transferred to *Aname* from other genera. The definition of *Aname* could then be enlarged to include the following characteristic: male with spine-bearing spur on tibia I. This has been deduced from the observation that there are in fact diplurine species in coastal and mountainous Queensland, the females of which could be attributed to either *Aname* (as defined above) or *Ixamatus,* but in which the males have a tibial spur, thereby excluding them from *Ixamatus.*

The recently described genus *Kiama* (Main and Mascord 1971) is distinguished from the

above genera as follows: from *Chenistonia*, *Dekana* and *Aname* by the absence of a tibial spur in the male and the presence in the female of several ventral spines instead of a basal pair on the palp tarsus; it differs from all the other diplurine genera in the deeply procurved U-shaped fovea and broad sternum with large, tear-drop shaped sigilla and from all genera (except an undescribed form in the MacPherson Range) by having no leg scopula in the female

STANWELLIA Rainbow and Pulleine 1918

Stanwellia Rainbow & Pulleine, 1918. Rec.Austr. Mus. 12: 164. Type species by monotypy *Stanwellia decora* Rainbow & Pulleine 1918 = *Stanwellia hoggi* (Rainbow 1914).



Figures 1-8.—1, 2. *Aname pallida* Koch, Holotype. 1, carapace, note eyes and fovea; 2, sternum, damaged and shape distorted. 3(♀), 4(♂), 5a(♀), *Chenistonia*. 3, sternum and labium; 4, right leg I, retrolateral view, note tibial spur; 5a, profile of eye tubercle. 5, 6, 6a, 7, 8, *Stanwellia*. 5, profile of eyes; 6, sternum and labium; 6a, labium of another specimen with more cuspules. 7, ♀ palp tarsus, ventral; 8, *S. decora* Rainbow and Pulleine, lectotype, dorsal view of eyes [= *S. hoggi* (Rainb.)]. 7a, *Chenistonia*, ♀ palp tarsus, ventral.

Description

Carapace long and narrow, roughly a truncated oval; caput low. *Fovea* shallow, straight or very slightly procurved. *Eyes* raised but not on a distinct tubercle, group broader than long (fig. 5). *Sternum,* long and narrow; sigilla usually small and submarginal (fig. 6).

Labium broad, anteriorly straight or only slightly indented, usually with a few anterior cuspules (fig. 6, 6a).

Chelicerae with continuous row of teeth on promargin of furrow only, with a small basal group on retromargin; sometimes with teeth or stout bristles (like a rastellum) above fang base (fig. 29). Palp tarsus without spines (fig. 7), scopula present, claw with prolateral row of teeth only. Legs, no spines on anterior two pairs of tarsi. Scopula present on tarsi I and II and apical part of metatarsi I and II, usually present on tarsi III, present or absent on tarsi IV. Legs often with pattern of dark blotches or annulations. Abdomen usually with speckled pattern or irregular bands consisting of a dark, median branched area (approximating to the heart outline) with laterally, an irregular pattern of yellow patches. Two pairs of spinnerets, terminal joint of posterior pair elongate and pointed. Tibia I of male with spines but no spur (figs. 9, 15, 19, 21, 26, 35 and 42. Palp tibia with few or no spines. Stigma broad and flanged, with embolus extending as a point at tip. No clear demarcation between stigma and bulb.

Diagnosis

No spines on female palp tarsus; eyes may be raised but not on a tubercle; posterior sternal sigilla small, often round, sub-marginal; truncate labium usually with cuspules; characteristic dark "smudges" or speckled pattern on legs in life. Male lacks spur on tibia I; stout, broad palpal stigma indistinctly demarcated from bulb. Female internal genitalia with either two large basal mound-like areas with ducts leading to small vesicles or a single basal area from which the vesicle stalks arise.

Affinities

Very similar to the New Zealand genus *Aparua* from which it is distinguished by the latter having a double row of teeth on the female palp claw.

The genus has no close affinity with any other Australian genus.

The present author recognises the following six species: *Stanwellia hoggi* (Rainbow), *S. grisea* (Hogg), *S. pexa* (Hickman), *S. nebulosa* (Rainbow and Pulleine), *S. occidentalis* sp. nov. and *S. inornata* sp. nov. Additional specimens, the specific status of which is undecided, have also been collected by the author from several localities.

Stanwellia hoggi (Rainbow 1914)

Chenistonia hoggi Rainbow 1914. Rec. Austr. Mus. 10: 240-2.
Stanwellia decora Rainbow & Pulleine 1918. Rec. Austr. Mus. 12: 164-5.
Aname decora Rainbow and Pulleine 1918. Rec. Austr. Mus. 12: 149-150. HOMONYM.
Stenwellia decora Rainbow and Pulleine in Main "Spiders of Australia" (Jacaranda 1964, 1967).

Types

Holotype of *Chenistonia hoggi* Rainbow: female from North Sydney (Australian Museum K31010).

"Type" of *Stanwellia decora* Rainbow and Pulleine: Female from Stanwell Park, Australian Museum K40955, herein designated as the lectotype.

"Cotype" female, *S. decora* from Stanwell Park N.S.W., Aug. 1910, in the South Australian Museum, herein designated as paralectotype.

Holotype female, *Aname decora* Rainbow and Pulleine. Clifton Gardens, Sydney (Australian Museum K 40923).

Notes on synonymy

Since by transferring the species *Aname decora* Rainbow and Pulleine to *Stanwellia* this name becomes a homonym of *S. decora* Rainbow and Pulleine, it should be replaced by another name. However since *A. decora* is here regarded as a synonym of *S. decora* this is not necessary. Although *A. decora* has precedence in the same publication over *S. decora*, under the provisions of Article 24a of the International Code for Zoological Nomenclature, it is justifiable to give priority to *S. decora.* Furthermore both *A. decora* and *S. decora* are junior synonyms of *Chenistonia hoggi* Rainbow.

Description of lectotype of Stanwellia decora *Rainbow and Pulleine.*

Carapace, length 9.0 mm, width 7.7. *Fovea* slightly procurved. *Eyes* raised, length of group 0.85 mm, width 1.85 mm, anterior row almost straight in front, very slightly procurved (fig. 8).

Chelicerae, left paturon with one small and nine large teeth on promargin, about 21 in basal posterior cluster.

Labium, length 1.0 mm, width 2.0 mm, 2 cuspules.

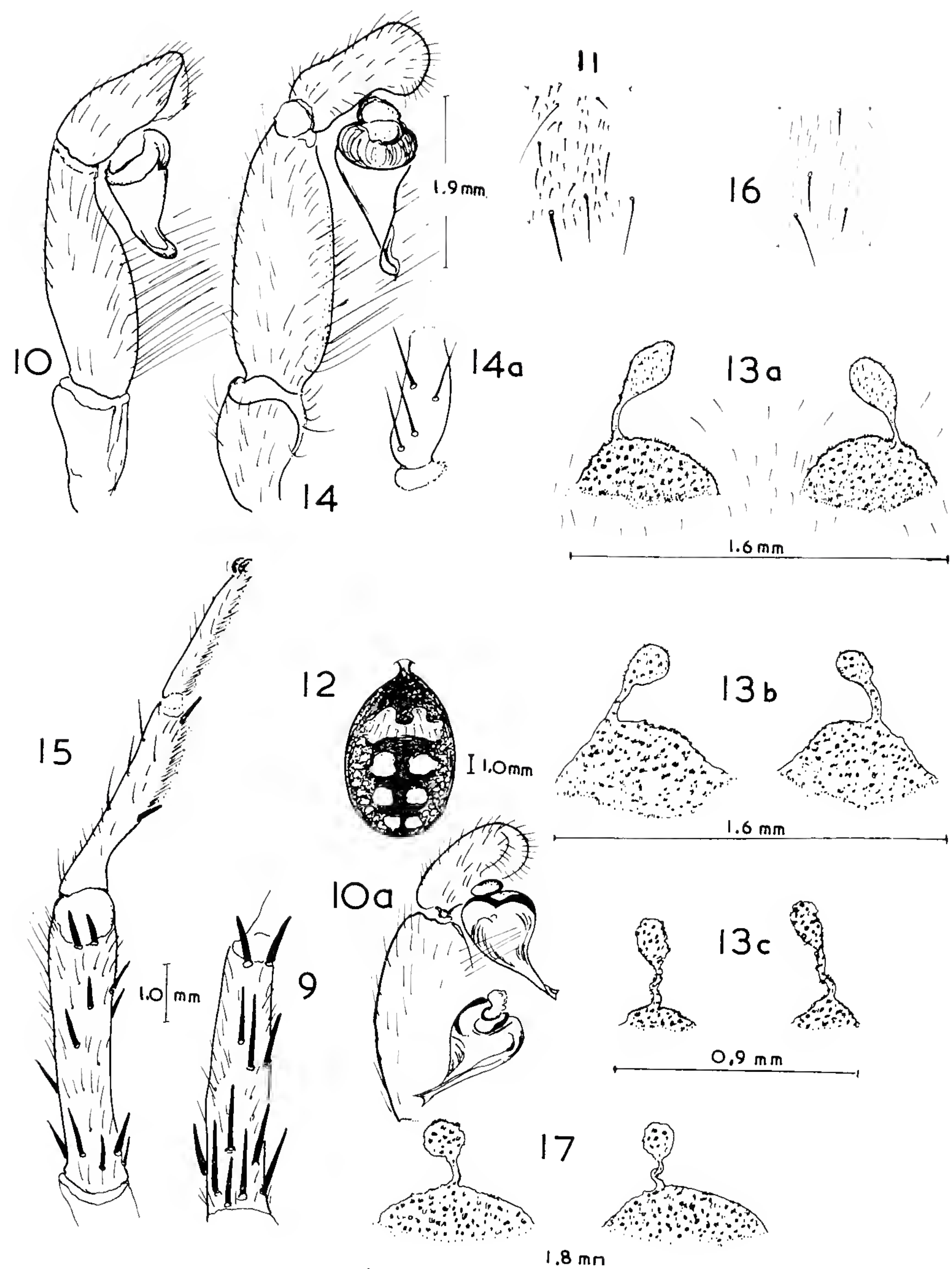
Sternum, length 5.0 mm, width 4.1 mm, Posterior sigilla small oval, submarginal.

Legs: Scopula complete on all tarsi and metatarsi I and II, apical half of metatarsi III and a few apical hairs on metatarsi IV

Leg formula	4	1	2	3
	3.14	2.91	2.68	2.36

	F	P	Ti	Mt	Ta	Total
Palp	5.0	2.6	3.5	....	3.4	14.5 mm
I	7.6	4.6	5.3	5.0	3.7	26.2 mm
II	6.8	4.5	4.8	4.5	3.6	24.2 mm
III	5.8	3.6	3.6	4.8	3.5	21.3 mm
IV	7.5	4.1	6.2	7.0	3.5	28.3 mm

Width patella I at knee = 1.5, Tibial index = 15.15
Width patella IV at knee = 1.5, Tibial index = 14.56



Figures 9-17.—9, 10, 10a, ♂ *S. hoggi* (9, 10 specimen in Hope Museum). 9, right tibia I, ventral; 10, right palp, retrolateral; 10a (Kiama specimen) right palp (Australian Museum KAI). 11, 12, 13a b c, 14, 14a b, 15, *S. Grisea* (Hogg). 11, mid-dorsal abdominal pilosity (number of hairs and bristles in area 1.0 mm across), (BYM 65/11); 12, dorsal abdominal pattern (BYM 65/32); 13a, b, c, ♀ internal genitalia (BYM 65/11, 65/16, 65/693 respectively); 14, ♂ right palp retrolateral, 14a, tibia prolateral (BYM 65/27); 15, right leg I, prolatero-ventral (BYM 65/27); 16, 17, *S. nebulosa* (Rainbow). 16, abdominal pilosity (BYM 59/425); 17, ♀ internal genitalia (BYM 59/425).

Spines: Absent from all tarsi, including palp. Present on following segments:

I, Metatarsus, 3 ventral; Tibia, 4 ventral, 2 prolateral; Femur, 1 dorsal.

II, Metatarsus, 4 ventral, 1 prolateral; Tibia, 6 ventral bristles, 2 prolateral; Patella, 1 dorsal; Femur, dorsal? (detached).

III, Metatarsus, 6 ventral, 6 dorsal, 2 prolateral, 1 retrolateral; Tibia, 6 ventral bristles, 2 prolateral, 2 retrolateral; Patella, 3 prolateral; Femur, 3 dorsal bristles.

IV, Metatarsus, 7 ventral, 6 dorsal, 4 prolateral, 1 retrolateral; Tibia, 6 ventral, 2 retrolateral; Femur, dorsal bristles.

Palp, Tibia, 4 apical spines, also 4 sockets where spines or bristles have been removed.

Abdomen: Brownish colour with yellow mottlings, about 12.00 mm long.

Specimens examined

Types and other specimens named by Rainbow: Lectotype, Paralectotype and three other specimens labelled as *Stanwellia decora* by Rainbow: two Females (K40958) and one immature (K41456), all from Stanwell Park August 1908, (examined by present author in 1954); these specimens agree generally with the lectotype. Holotype of *Aname decora* Rainbow & Pulleine, and holotype of *Chenistonia hoggi* Rainbow.

Other specimens: Males. Two previously unidentified male specimens in the Hope Museum, Oxford, collected from Sydney in 1869; one of these specimens with four labial cusps, ten ventral spines on tibia I (fig. 9) and palp with bluntly pointed stigma (fig. 10); no spines on palp tibia.

A male specimen (Australian Museum KA1) collected by R. Mascord from Kiama, N.S.W., 22 June, 1965. The specimen was found wandering at night near burrows of *Dyarcyops* with which genus it was at the time identified. The specimen has a carapace length of 7.7 mm, marginal bristles present; labium with four labial cusps; abdomen with four pairs of yellowish blotches on dark brown background; colour generally dark brown with golden sheen. The palp tibia and stigma as figured (fig. 10a); right palp with no prolateral spines on tibia, left palp tibia with two delicate prolateral spines. Ten ventral spines on tibia I, but with different disposition on the left and right legs.

Leg formula

4	1	2	3
3.36	3.07	2.87	2.66

Tibial index I = 12.35; Tibial index IV = 12.50

Stanwellia grisea (Hogg 1901)

Aname grisea Hogg, 1901. Proc. Zool. Soc. London, 1901 (vol. 2): 252-254, fig. 30.
Stanwellia grisea Main: "Spiders of Australia" (Jacaranda 1964, 1967).

New synonymies:
Aname arborea Hogg, 1901. Proc. Zool. Soc. London, 1901 (vol. 2): 254-5, fig. 31.
Aname pellucida Hogg, 1901. ibid pp. 255-6, fig. 32.
Ixamatus gregori Hogg, 1901. ibid pp. 258-9, fig. 33.
Chenistonia major Hogg, 1901. ibid pp. 263-4, fig. 36.
Aname butleri Rainbow & Pulleine 1918. Rec. Austr. Mus. 12: 157-8, fig. 112. (Lectotype only; see note below on types).

Notes on types and synonymies

Aname grisea, arborea, pellucida, Ixamatus gregori and *Chenistonia major,* all in British Museum (N.H.) and all seen by the author in 1958:

Aname grisea: The "type" series (30.2.10-15) consists of three juvenile specimens, the largest (which is here designated as lectotype) with carapace length of 4.0 mm. All are pierced longitudinally with pins but are now in spirit. Locality, Macedon, Victoria (Hogg 1901).

Aname arborea: A female (herein designated as lectotype) and juvenile in the one tube (03.2.10-17); female with carapace length of 5.5 mm. Locality, Macedon (Hogg 1901).

Aname pellucida: Labelled 'type' and 'collected at Bacchus Marsh' (03.2.10-16). The tube contains a juvenile specimen and badly damaged female with carapace length of 8.0 mm which is herein designated as lectotype.

Chenistonia major (03.2.10.7.8): Seven females. with carapace lengths of 4.0 mm, 8.0, 10.0 (3 specimens), 10.5, 11.0 mm (the latter designated as lectotype). Locality, Macedon.

The specimens described by Rainbow and Pulleine (1918) as males of *Chenistonia major* Hogg (two specimens in the one tube, labelled "allotype" K40968, Australian Museum) are not the same species as the specimens named by Hogg (1901) as *Chenistonia major* (here synonymised with *Stanwellia grisea* (Hogg) but are the previously undescribed males of *Chenistoni tepperi* Hogg. Also, in the South Australian Museum there are two male specimens labelled "cotype ♂, *Chenistonia major* Hogg ♂, Morialta Gully S.A.", these are thought to be from Rainbow and Pulleine's collection. They are not *Stanwellia* specimens but either *Chenistonia* or *Dekana.*

Ixamatus gregori, a single adult male specimen (1903.2.10.14), labelled "type" which is therefore the holotype. Locality, Macedon.

Aname butleri, Australian Museum (K41482) and seen by the author in 1954. It is labelled 'type' and the locality is Merri Creek, Melbourne. I herein designate it as lectotype. This specimen (lectotype) is not a female but (as deduced from the swollen palps) an immature male. In the Australian Museum there are four additional females labelled as *Aname butleri* [K41614, also labelled "type" (one specimen) and K41615, labelled "co-types" (three specimens)]. These four specimens are not Diplurids but Ctenizids and I regard them as *Dyarcyops.* With K41614 there is another label stating:— "this is not holotype (D. R. McAlpine 22.8.52)."

Diagnosis

Female: Colour in life generally a dark brown; dorsum of abdomen with short, sparse pile (fig.

11), pattern of yellow mottlings on dark background, variable, may be of uniform 'speckles' or consist of lateral yellow blotches alongside a dark median section overlying the heart (fig. 12), sometimes posteriorly with dark bands; venter usually uniformly pale or with dark flecks; legs paler usually with dark blotches, sometimes with distinct annulations. Carapace low, caput rounded. Labium with variable number of cuspules, two to six. Carapace length of specimens measured, up to 9.7 mm.

Leg formula of a specimen with carapace length of 7.2 mm (Mount Macedon, BYM 65/16):

4	1	2	3
2.93	2.47	2.32	2.12

Tibial index I, 15.71; tibial index IV, 15.38.

Internal genitalia consist of two broad denticulate basal structures which, when viewed dorsally, appear as two mounds but which are in fact the mouths of two funnels leading into the 'spouts' or narrow ducts connected with the blind vesicles (figs. 13a, b and c).

Male (see fig. 42). Palp and tibia I (BYM 65/27) as figured (figs. 14 and 14a and 15). Carapace with dense marginal bristles. Differs from *S. pexa* and *S. nebulosa* by having more spines on prolateral aspect of palpal tibia. Carapace length of holotype of *Ixamatus gregori* (= *S. grisea*) 4.0 mm, and of two specimens of *S. grisea* collected by the author, 7.3 (BYM 65/23) and 7.5 mm (BYM 65/27).

Leg formula BYM 65/27.

4	1	2	3
3.2	3.03	2.89	2.45

Tibial index I = 13.58, Tibial index IV = 14.63.

Specimens examined and localities

Types as listed above and the following specimens (collected by the author except where otherwise stated).

Females and juveniles: 20, Macedon, V.; Grampian Mountains, V. 5, Barney's Creek; 1, Dairy Creek Road; 1, Stony Creek Road, about two miles from Silver Band Falls; 1, Mt. Victory Road; 2, Chatauqua Park Road; 1, Mt. William Road (near top); 1, Mt. William Road, near turnoff; 4, three miles east of Myrtle Bank. Dandenong Range: 6 and one brood, Ferntree Gully, half a mile from station; 4, Sassafras Road; 1, Highett, V. (collected by E. Swarbreck and sent to the author by Professor Hickman who had labelled the specimen *Aname butleri*).

Males: 2, Macedon, V. These two specimens collected as penultimate instar males on 12.ii.1965 and held in flowerpots of soil. They moulted to maturity late February/early March.

Natural history

The spiders have a simple open burrow, with sparse silk lining. The burrows are made in damp situations of the forest floor, in deep humus and moss or amongst leaf litter. They often occur in undisturbed, wet road banks. The species appears characteristically to inhabit gullies of mountainous areas and fringes of swampy areas where the soil is fairly well drained. Some have been found in moss and bark at the base of tree trunks.

Stanwellia nebulosa (Rainbow and Pulleine 1918)

Aname nebulosa Rainbow & Pulleine, 1918. Rec. Austr. Mus. 12: 147-8.
Stanwellia nebulosa (Rainbow & Pulleine) in Main, "Spiders of Australia" (Jacaranda 1964, 1967).
New syn. *Aname confusa* Rainbow and Pulleine, 1918. Rec. Austr. Mus. 12: 155-7.

Notes on Types

Male "type" of *Aname nebulosa*, (Australian Museum, K40924), Mallala, S.A., 23.iv.1905. The collection date of this specimen is given as March 23 in Rainbow and Pulleine (1918).

The description of the male specimen precedes that of the female, therefore the male 'type' is herein designated as the lectotype of the species *Stanwellia nebulosa* (Rainbow and Pulleine).

♀ "type" of *Aname nebulosa*, Tea Gardens, Mt. Lofty, S.A., 4.xi.17, (Australian Museum K40926).

2♀♀ ("cotypes") (Austr. Mus. K41460), Mallala, S.A.; ♀ ("cotype") (Austr. Mus. K40930), Meningal, S.A., May 1908, [date given as 'July 1917' by Rainbow and Pulleine (1918)]. Specimens numbered as follows: Australian Museum K40926, K41460 (2 specimens), and K40930 are herein designated as paralectotypes. They were sighted by the author in 1954. ♀ 'cotype' *Aname nebulosa*, Aldgate S.A. May 24, 1910, in the South Australian Museum (sighted by the present author in 1952) and herein designated as a paralectotype. Rainbow and Pulleine (1918) also mention a specimen from "Scott's Creek" of which the whereabouts is not known.

Diagnostic description

Female: General appearance as in Fig. 43. Carapace length of paralectotype (Australian Museum K40926) 8.7 mm; leg formula:

4	1	2	3
2.71	2.27	2.27	1.94

Tibial index I, 15.78; tibial index IV, 15.38.

In life specimens are a dark, dusty brown with golden hairs and a yellow, speckled pattern on abdomen dorsum, legs paler with dark smudges. Abdomen with dorsal pile of fine hairs (fig. 16).

Internal genitalia as figured (fig. 17); similar to *S. grisea* and *S. pexa*.

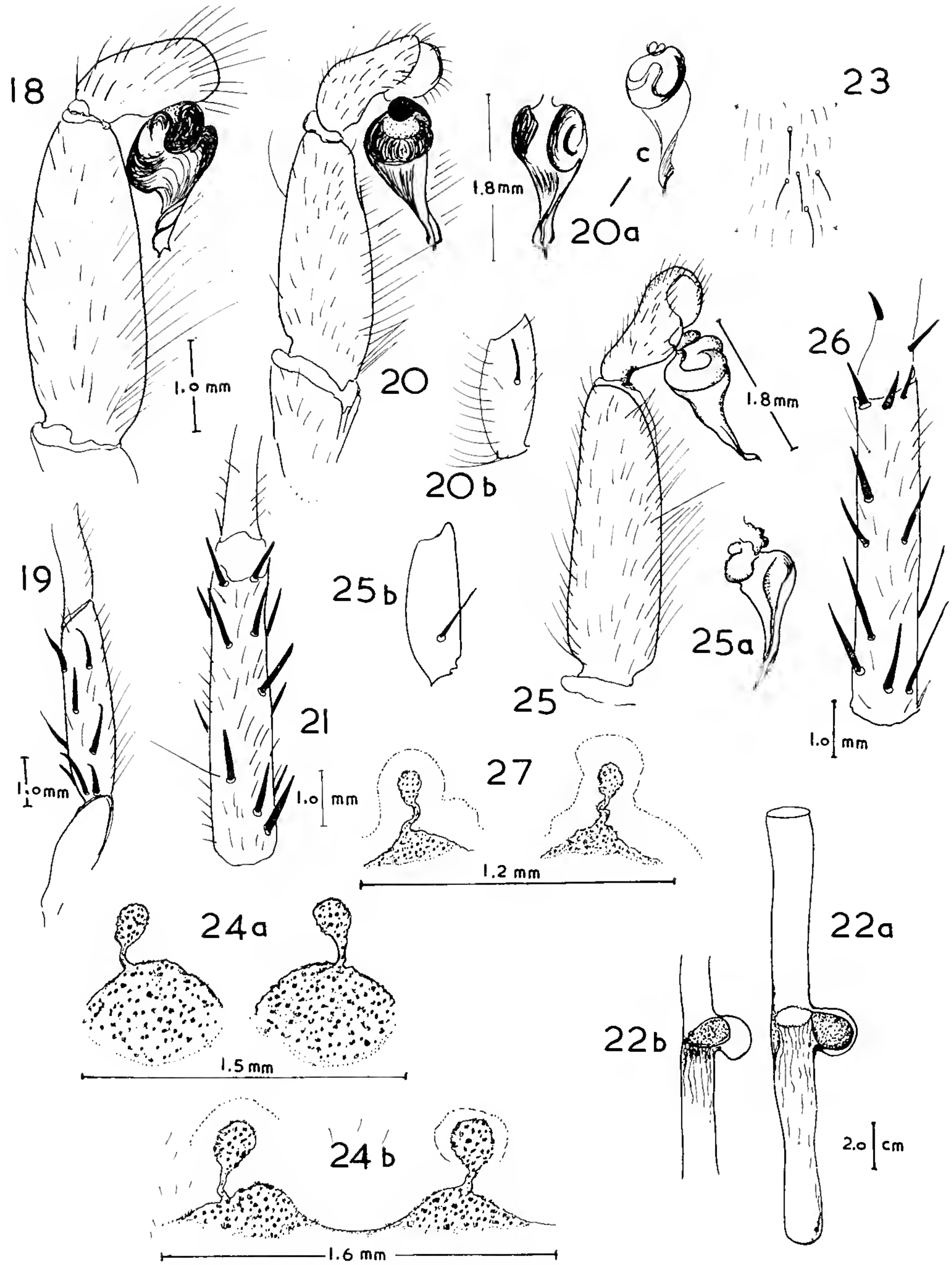
Male: Palp and tibia I as figured (figs. 18, 19 ♂ lectotype, figs. 20, 21 of BYM 54/547). Stigma long and bluntly pointed at tip; palp tibia with one large stout prolateral spine in mid region, one spine absent. Tibia I with eight ventral spines. Carapace length of lectotype 5.3 mm; carapace length BYM 54/547, 8.0 mm. The legs of the lectotype were damaged but the leg formula of BYM 54/547 is as follows:

4	1	2	3
3.93	3.60	3.52	3.10

Tibial index I = 11.11, Tibial index II = 11.90.

Specimens examined and localities

Types as above and the following specimens collected by the author (except where otherwise stated):



Figures 18-27.—18-22, *S. nebulosa.* 18, 19, ♂ lectotype, 18, right palp, retrolateral; 19, right tibia I, prolateral; 20, ♂ right palp retrolateral (BYM 54/547); 20a, c, different aspects of stigma (fig. 20c shows the same aspect as in fig. 18), 20b prolateral view of tibia; 21, ventral view right tibia I (BYM 54/547); 22a, b, longitudinal section of burrow, showing "open" position of 'pebble' in side pocket (a) and in 'closed' position (b). 23-27, *S. pexa* (Hickman). 23, 24a, (♀ specimen from Queens Domain, Tasmania, V.V.H. BYM 70/38); 23, abdominal pilosity; 24a, internal genitalia. 24b, ♀ internal genitalia (BYM 54/65); 25, a, b, ♂ palp retrolateral view, a, stigma rotated, b, tibia prolateral aspect (BYM 54/66); 26, tibia I ventral (BYM 54/66); 27, ♀ internal genitalia (BYM 70/36) (Tasmania W. coast near mouth Arthur R., V.V.H.)

Females and juveniles: South Australia: 1, Aldgate; 3, Bute; 4, Blackwood (including 1 penultimate instar ♂); 8, Blanchetown; 1, Dublin; 3, Willunga Hill, Kuitpo; 1, Nairne; 2, Port Broughton, 8 miles south; 1, Port Germain Gorge; 1, Tarlee; 2, Tintinara, 2 miles south; 1, Mount Lofty; 2, Stirling; 6, Wirrega, Victoria: 3, Nhill, 10 miles west (east of Lowlait Ranges). One female forwarded by Professor Hickman. This specimen was collected by Dr. R. H. Pulleine and the locality given only as "South Australia".

Male: Specimen BYM 54/547 was collected as an immature specimen from Willunga Hill, Kuitpo, S.A., on 18 December, 1954. The specimen was not obviously a male and was kept for observation in a flowerpot of soil in which it made a characteristic burrow. It was found to be mature on 2 April, 1956.

Natural History

The spiders build a distinctive vertical burrow. The entrance may have a small collar of leaves but the upper section is unwebbed. The lower half is silk-lined. A pear-shaped pebble made by the spider of compacted soil is attached to one side of the free, collar-like upper part of the silk lining. The pebble is so counterweighted, that when the spider is disturbed and pulls on the silk collar, it falls across and blocks the burrow lumen (see figs. 22a, b). Rainbow and Pulleine (1918, pp. 82-3, pl. 20) originally described this curious structure, and Main (1964, 1967, pp. 44, 45) again figured and described it. Specimens in captivity have also been observed constructing the characteristic burrow.

The species generally occurs in drier situations than do the eastern species. It extends from damp situations in gullies of the Lofty Mountains near Adelaide, eastward into the dry limestone soils of the mallee region of south-eastern S. A. and western Victoria and northwards through the Flinders Range to Port Augusta.

Stanwellia pexa (Hickman 1929)

♂, ♀ *Aname Pexa* Hickman, 1929. Proc. Roy. Soc. Tasmania, 1929, 87-97, figs. 1-6.

Types

Queen Victoria Museum, Launceston, Tasmania.

Type locality, Prince of Wales Bay, Derwent Park (not seen by the present author). The male description precedes that of the female and is herewith designated as the lectotype, and the female as paralectotype.

Hickman in his description of the female (Hickman, 1929) states the claw of the female palp "with a double row of teeth". However, I noted that on a specimen sent by Professor Hickman to the British Museum (Natural History) teeth were present only on the prolateral side of the palp claw [B. M. (N. H.) Register No. 1931. 70.30.5]. Professor Hickman (in litt.) has now confirmed that his original statement was in error and that *S. pexa* has only a single row of teeth on the palpal claw.

Female: Dark coloured and with conspicuous markings on legs, abdomen irregularly mottled or banded. Sparse pile of fine hairs and bristles (fig. 23). Internal genitalia similar to *S. grisea* and *S. nebulosa*. The basal funnels may be large (fig. 24a) or small (fig. 24b). Specimens with carapace length up to 12.9 mm.

Male: Palp and tibia I as figured (figs. 25, 26), specimen from Fisher Island (BYM 54/66). The palpal stigma is generally relatively longer and more tapering than that of other species. Carapace length of mature males is variable: male type 7.0 mm. (Hickman 1929); male from The Domain, Hobart, Tasmania, 7.0 mm; of four males from Fisher Island, carapace lengths as follows: 8.7, 9.0, 9.7 and 10.00 mm. Leg formula and tibial indices of BYM 54/66.

4	1	2	3
3.57	3.36	3.26	2.84

Tibial index I = 12.17, Tibial index IV = 12.82

Leg formula of male type [calculated from Hickman's measurements (Hickman 1929, pp. 87-8)].

4	1	2	3
3.26	2.87	2.78	2.43

Tibial index I, 14; tibial index IV, 14 (Hickman 1929).

Specimens examined and localities

1♀ British Museum specimen. 6♀♀, 4♂♂ Fisher Island (collected by V. N. Serventy); 2♀♀ from Queen's Domain, Hobart and 1♂ from The Domain Hobart, Tasmania (collected by V. V. Hickman); 3♀♀ from north of mouth of Arthur River, west coast Tasmania (collected by V. V. Hickman), tentatively identified as *S. pexa*, internal genitalia of one specimen as in fig. 27 (BYM 1970/36).

Natural History

Hickman (1929) described the burrow as being vertical with a collar of grass stalks at entrance and with a swelling near base, the whole with only a sparse lining of silk. Burrows were up to 15.0 cms. deep and were in a bank about ten yards from the sea-shore in a patch of scrub. V. N. Serventy reported (personal communication) that vertical and oblique burrows, all without any closure, were constructed by specimens on Fisher Island.

Stanwellia occidentalis sp. nov.

Types

Holotype ♀, mouth of the Todd River north of Port Lincoln, Eyre Peninsula, South Australia, collected by B. Y. Main, 16 December, 1952 (BYM 52/533). Australian Museum No. K69302.

Paratype ♀, Cummins Plains, east of Cummins, Eyre Peninsula, S.A., collected by B. Y. Main, 16 December, 1952 (BYM 52/561). Specimen with young in burrow. Australian Museum No. K69301.

Paratype ♀, Cummins, 8 miles east, Eyre Peninsula, S.A., collected by B. Y. Main 17 December, 1952 (BYM 52/575), South Australian Museum No. N19719.

Description of holotype

Female (fig. 28). Carapace glabrous, dark brown, almost straight sided. Legs pale coloured with dark brown blotches and annulations as

follows: I and II, femur with proximal and distal annulation; patella distal annulation; tibia, proximal and distal annulation; metatarsus and tarsus, pale with dark smudges; III and IV, faint annulations on femur, patclla tibia, pale coloured metatarsus and tarsus. *Carapace* 3.9 mm long, 2.9 mm wide, caput 2.3 mm wide. *Fovea* almost straight, slightly procurved. *Abdomen* 6.0 mm long, 3.8 mm wide, almost straight-sided. Sternum 1.9 mm long, 1.6 mm wide, sigilla indistinct (fig. 29). Labium 0.5 mm long, 0.65 mm wide, 1 cuspule. *Maxillae* with about 16 cuspules. *Chelicerae*, promargin of groove with 7 teeth, a basal outer cluster of about 15 granules. Rastellum of heavy teeth above base of fang, and around apical angle (fig. 29); teeth not on a process. This rastellum is as pronounced as in many Ctenizidae, for example as in *Dyarcyops*.

Spines. Palp, tibia 8 ventral. I, metatarsus 4 ventral, 1 prolateral; tibia, 3 retroventral. II, metatarsus, 5 ventral, 1 dorsal; tibia, 3 (bristle-like) ventral. III, metatarsus, 4 ventral, 5 dorsal, 3 prolateral; tibia, 3 dorsal, 2 prolateral; patella, 3 stout prolateral (like a Ctenizid). IV, metatarsus, 7 ventral, 3 dorsal, 1 prolateral; tibia, 1 apical ventral.

Scopula complete on tarsi I and II and palp and metatarsus I; apical hairs on metatarsus II, absent on third and fourth legs. Trichobothria few, up to 6 or 7 in dorsal irregular line on tarsus, metatarsus and tibia.

Leg formula	4	1	2	3
	2.46	2.35	2.1	1.74

Tibial index I, 14.28; tibial index IV, 15.78.

Abdomen oval, almost straight sided with a dark median area, otherwise a uniformly mottled pattern of yellow flecks. Sparse pile of hair. Terminal segment of posterior spinnerets relatively short and pointed. Internal genitalia not dissected but can be distinguished through thc integument as being of the dual 'mound' or 'funnel' type, i.e. with two clearly separated basal mounds. Genitalia of one paratype dissected (fig. 30). Carapace length paratype (BYM 52/575), 4.1 mm; paratype (BYM 52/561), 6.4 mm, this being the largest specimen of the species observed.

Natural History

The holotype was collected from a simple burrow in a sea cliff, overlooking the mouth of the Todd River. The cliff face was overhung by shrubs. High tide washed the cliff base. A flimsy cocoon of eggs was found in the burrow. It contained eleven subspherical eggs, all at an early developmental stage, with diameter of 2.0 mm.

The Cummins specimens occured under mallee, two in moss-grown creek alluvium, two under mallee litter; the "Coomunga Springs" spider was found with other mygalomorphs under an isolated clump of bottlebrush in a grassy, farm paddock; the Streaky Bay spider was under casuarinas. The silk-lined burrows have the mouth formed into a silk collar, which may be retracted to close the burrow. A soil plug may be placed beneath the closed collar thus effectively sealing the nest. In the sealed burrow of one paratype (BYM 52/561) was a cluster of fifty-five recently hatched spiderlings; these had no pigment and had carapace lengths of 1.1 or 1.2 mm.

Adult Male unknown.

Specimens examincd and localities

S.A.: ♀, mouth of the Todd River north of Port Lincoln, Eyre Peninsula, (holotype); 2, Cummins, 8 miles east, (includes paratype, BYM 52/575); 1, Cummins Plains (paratype BYM 52/561); 1, "Coomunga Springs", west of Port Lincoln.

Immature males: 1, Cummins, 8 miles east; 1, Streaky Bay, east of; 1, Port Lincoln.

W.A.: 2 juveniles and one immature ♂ (?), Porongorups Range (near Bolganup dam), (collected by J. Springett by sieving litter and humus); 1 juvenile 3 miles north of Mammoth Cave, W.A.

The Western Australian specimens and other South Australian specimens all agree with the holotype in the presence of a definitive 'pseudo-rastellum', uniformly mottled abdomen, the distinctive annulations on the legs, absence of scopula on third and fourth tarsi and fewer spines on the legs, especially of the third and fourth. It is the combination of these features and the small size which distinguishes *occidentalis* from the other species.

Stanwellia inornata sp. nov.

Types

Holotype, ♀, Rose's Gap, Grampian Mountains, Victoria, collected by B. Y. Main, 28 November, 1965 (BYM 65/704), [Australian Museum No. K69299]

♂ Paratype (BYM 65/706), [Australian Museum No. K69300]

♀ Paratype (BYM 65/711), [National Museum No. K-25]

Data for paratypes as for holotype.

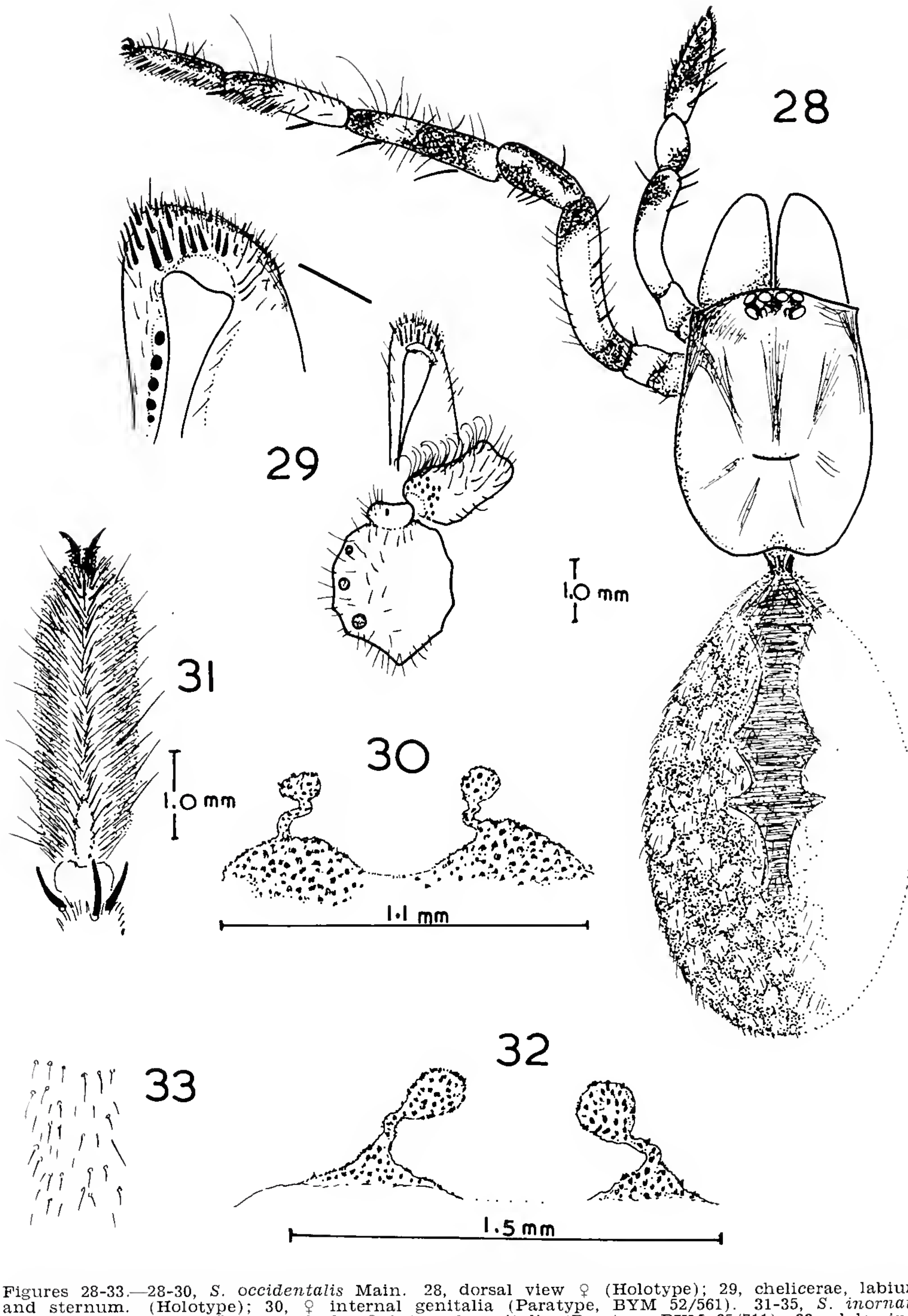
Description of Holotype

Female: Carapace length, 8.8 mm, width 7.3 mm. Colour, uniform dusky brown, in life no pattern visible on legs or abdomen, generally brown and hairy-looking with golden sheen. Fovea almost straight. Anterior width of eye group 1.8 mm. *Labium*, length 1.1 mm, width 1.7 mm, 2 cuspules, sternum length 4.9 mm, width 3.8 mm, sigilla oval. *Chelicerae* with 9 teeth on promargin of furrow, basal cluster on outer margin extending up to about fourth inner tooth. Palp tarsi each with single basal fine tapering spine. Legs, scopula present on all tarsi and metatarsi I and II, a few apical hairs on metatarsi III. Scopula of tarsi III and IV divided by band of median bristles (fig. 31). Tarsal claws with 4 to 8 teeth in each comb of bipectinate claws.

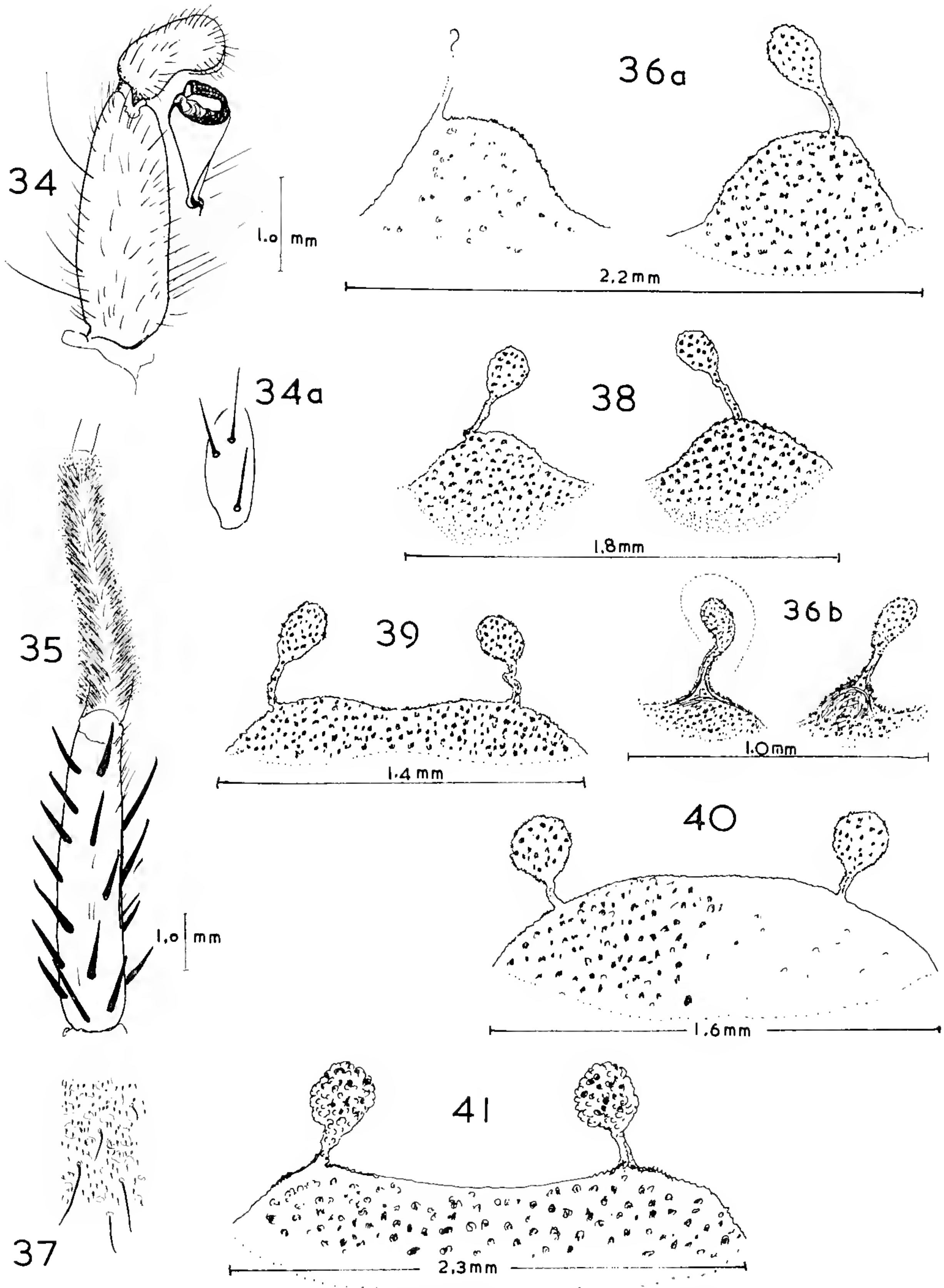
Leg formula:	4	1	2	3
	2.57	2.55	2.31	2.23

Tibial index I, 14.6, Tibial index IV, 14.7

Spines. Distribution of spines as follows: No dorsal spines or bristles on femurs. I, Metatarsus, 2-1-2 ventral; Tibia, 3 apical ventral spines and 3 ventral bristles, 3 prolatero-dorsal. II. Metatarsus, 2-2-2 ventral, 1 prolateral; Tibia,



Figures 28-33.—28-30, *S. occidentalis* Main. 28, dorsal view ♀ (Holotype); 29, chelicerae, labium and sternum. (Holotype); 30, ♀ internal genitalia (Paratype, BYM 52/561). 31-35, *S. inornata* Main. 31, left tarsus III, ventral; 32, ♀ internal genitalia (Paratype BYM 65/711); 33, abdominal pilosity (BYM 65/705).



Figures 34-41.—34-35, *S. inornata* (♂ paratype). 34, right palp retrolateral, 34a, tibia prolateral; 35, right tibia I ventral. 36-41, unidentified *Stanwellia* specimens. 36a b, ♀ internal genitalia, 36a (BYM 65/41), 36b (BYM 65/39); 37, abdominal pilosity (65/685); 38-41, ♀ internal genitalia, 38 (BYM 65/685); 39 (BYM 65/677); 40 (BYM 59/404); 41 (BYM 65/48).

3 spines and 3 ventral bristles. III, Metatarsus, 2-2-1 ventral; Tibia, 7 fine tapering ventral spines, 6 dorsal, 4 prolateral, 1 retrolatero-ventral; Patella, 1 dorsal; 4 stout prolateral; 2 retrolateral. IV, Metatarsus, 2-1-1-2 ventral, 2-1-2 dorsal, 1 prolatero-ventral; Tibia, 2 spines and 4 bristles ventral, 2 prolatero-dorsal.

Palp. Tarsus, 1 basal; Tibia, 2 apical ventral spines and 6 ventral bristles; 2 spines and 2 bristles prolateral.

Paratype Female: Carapace length 8.5 mm, width 6.5 mm.

Labium with 3 cusps. Internal genitalia consist of small basal, denticulate mounds connected by thin, bent tubes to globose vesicles (fig. 32).

Paratype male: Carapace length 7.0 mm, width 5.8 mm. Colour generally a uniform dusky brown, no pattern apparent on legs or abdomen in life. Carapace with dense marginal hairs. Generally hirsute, the hairs with golden sheen; abdomen with long fine bristles amongst the hairs. Palp as figured (fig 34); right tibia with three long fine prolateral bristles (fig 34a), left tibia with only two bristles. Tibia I with 7 ventral spines, 6 retrolatero-ventral, 6 prolatero-ventral (fig. 35).

Leg formula:

4	1	2	3
3.5	3.48	3.16	3.16

Tibial index I 12.36. Tibial index IV 13.25.

S. inornata differs from other described males of *Stanwellia* in having more attenuated palpal-stigma and relatively longer, thinner legs and lacks a distinct mottled colour pattern.

Specimens examined

Three types as above and two other females [of which one specimen (BYM 65/705) has four labial cusps; and abdominal pilosity as figured (fig. 33)], all from Rose's Gap, Grampian Mts., Victoria.

Distribution of S. inornata *and* S. grisea *in the Grampian Mountains*

The occurrence of what appear to be two species in the Grampian Mountains is notable. *S. grisea* occurs in the eastern gullies of the mountains, *S. inornata* has been found only along a creek in Rose's Gap (but probably extends farther). This latter area has a sandy soil type and a heath vegetation understorey which is distinct from the plant associations of the eastern regions. At this same locality *Aganippe* was also collected. This ctenizid genus has not been observed in the wetter, eastern localities of the mountain range.

Unidentified Stanwellia specimens examined

The following specimens were all collected by the author except where otherwise stated.

2 ♀♀ and 2 juveniles, Lakes Entrance, V. 1 ♀ Harris Creek, V. 3 ♀♀ and 1 juvenile, 30 miles from Orbost on Bonang Highway. The internal genitalia of two females (BYM 65/41 and 65/39 with two basal denticulate mounds as in figs. 36a and b. 1 ♀ Otway Ranges, V. This specimen (BYM 65/685) in life glabrous and a uniform, light tan colour, lacking dark smudges or annulations on the legs. Abdomen with short, thornlike bristles and long tapering bristles (fig. 37). Internal genitalia with large basal mounds (fig. 38). 5 ♀♀ Lake Mountain, V. One female (BYM 65/677) with internal genitalia as in fig. 39. 1 ♀ Mount Beauty, V. 9 ♀♀ Donna Buang, V; internal genitalia (BYM 59/404) as in fig. 40. 1 ♀, Mt. Ben Lomond (4000') Tasmania (collected by V. V. Hickman); 1 ♀ and 1 immature specimen Table Cape, Tasmania (collected by V. V. Hickman). 1 ♀ about 1 mile N. Piccadilly Circus, Brindabella Ranges, A.C.T. (internal genitalia as illustrated in fig. 41, BYM 65/48); 1 ♀ Uriarra State Forest, A.C.T. (BYM 65/44), internal genitalia similar to BYM 65/48; 1 ♀ Black Mountain, A.C.T. collected by A. R. Main; 1 ♀ Brindabella Ranges, A.C.T. collected by A. R. Main; 2 ♂♂ Coree Flats, Brindabella Ranges, A.C.T. collected by R. Pengelly. All these A.C.T. specimens were at first thought to be *S. hoggi*. Some of them were collected in association with *Dyarcyops fuscipes* (Rainbow), which is a common ctenizid of the Sydney and Blue Mountains' regions. However, when the Brindabella specimens were observed to have a distinctive type of internal genitalia (fig. 41), similar only to high, mountain-locality specimens from Victoria (Lake Mountain and Donna Buang, (figs. 39, 40) the possibility that they were of an

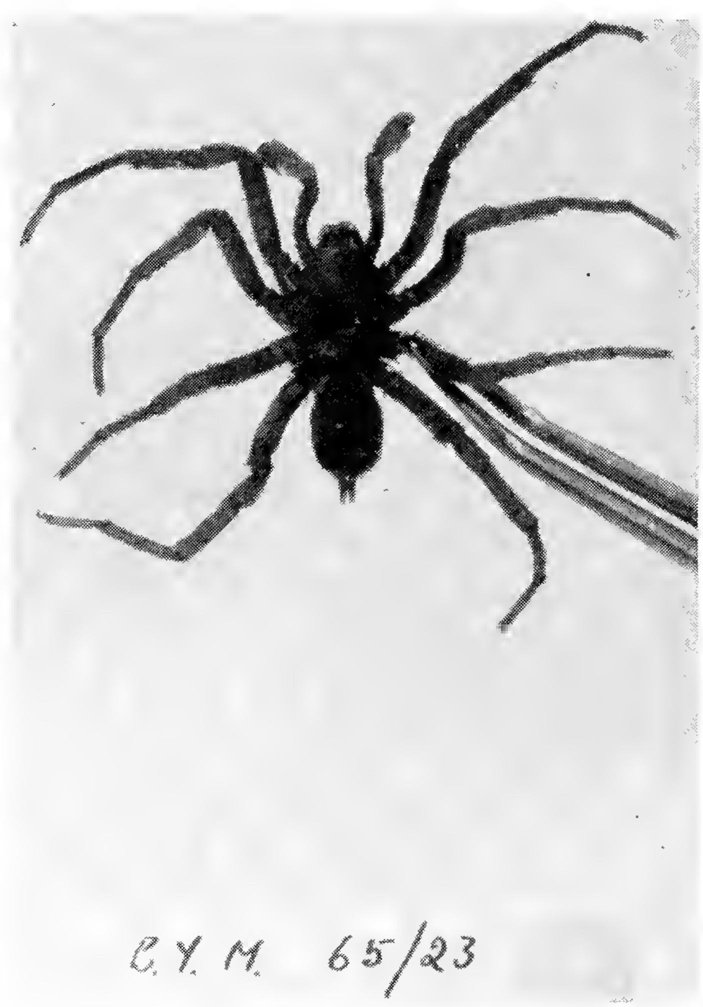


Figure 42.—*Stanwellia grisea* (Hogg) Dorsal view of male specimen. Note that there is no spur on tibia of first leg (BYM 65/23). (Natural size x 1.7)

Figure 43.—*Stanwellia nebulosa* (Rainbow and Pulleine) Dorsal view of female specimen (BYM 55/727) (Natural size x 1.8)

undescribed species. perhaps with relictual populations scattered along mountain tops of the southern part of the Dividing Ranges had to be considered.

Taxonomic Value of Female Internal Genitalia

Schiapelli and Pikelin (1962) and Forster and Wilton (1968) have used the internal female genitalia to distinguish genera and species of Mygalomorphae. The present author while regarding this structure as a useful guide, especially to *genera,* has noted variability of outline contours amongst specimens of the one species, as in *S. grisea* and *S. pexa.* Also the similarity of basic form between certain species is such that, alone, this character would not distinguish the species. Specimens of *S. grisea, pexa, occidentalis, inornata* and several unnamed populations all have the basic form of two mound-like 'funnels' each connected to a blind vesicle. The vesicle may be ovoid or spherical, the connecting duct straight or bent and the 'funnels' large and rounded or suppressed. It is possible that the degree of 'inflation' of the vesicles and basal mounds may be related to sexual activity of the animal. This requires investigation by collection and dissection of animals from the one locality at different times of the year. The degree of distension of the genitalia parts does not appear to be related to gross size of the animal but may possibly be affected by partial dessication. Unnamed high-mountain forms of *Stanwellia* have a single, broad basal mound giving off two ducts which connect to the vesicles (figs. 39, 40, 41). Probably this basal mound represents a fusion of two single 'funnels'. It is interesting that Forster and Wilton (1968) figured two basic forms of genitalia structure for the New Zealand genus *Aparua* which are similar to the two basic forms observed in the related *Stanwellia.* The structure of the internal genitalia of *S. hoggi* has not been observed.

Discussion

Biology and Life History

From collection dates of males and the seasonal occurrence of eggs in the burrow it is deduced that *Stanwellia* males wander and mate in the autumn and that eggs are laid in late spring. Presumably, young disperse in the autumn and early winter. It is possible that this biological association with an autumn/winter wet season has been the chief factor restricting the range of the genus northward into the summer rainfall/winter drought regions of Australia. The genus appears to be tied to autumn/winter rain for breeding and dispersal and at the same time requires continual year-round humidity (except possibly *S. nebulosa* which is the only species occurring in a region of severe summer-drought). *S. occidentalis* in Eyre Peninsula, and in the south-west localities of Western Australia, occurs in situations where the micro-habitat effectively simulates a continuously 'humid' environment.

Geographic Distribution

The distribution of *Stanwellia* is of interest for several reasons:

(i) It occurs in extreme types of habitats ranging from mountainous situations above the snow line (for example in the Brindabella Range, A.C.T., Lake Mountain and Donna Buang, Victoria and other localities in Victoria), on islands of the Bass Straight, to semi-desert habitats in the limestone country of western Victoria, eastern S.A. and to coastal cliffs just above the sea in Eyre Peninsula. Associated with these great habitat differences are behavioural adaptations, notably in the structure of burrows.

(ii) Occurrence of the genus in the south western corner of W.A. probably represents an isolated relict of an earlier continuity along the coastal strip from S.A. This particular westward extension in range of an essentially south-eastern Australian genus, appears to parallel the former range of some mammals, such as the Tasmanian devil and koala, fossils of which have been found in limestone caves of south-western W.A. Apparently, because of the smaller size and minimal area requirements of the spider it has been able to persist in restricted

localities after the mammals became extinct in the region. This disjunct distribution parallels in part that of the Mygalomorph family Migidae. An undetermined genus of the subfamily Calathotarsinae occurs in the Stirling Ranges and Porongorups in Western Australia and the Grampians and mountains north of Melbourne in Victoria (Main unpublished data).

(iii) The morphological similarity of *Stanwellia* and the New Zealand genus *Aparua* Todd indicates a close relationship between the two. Such a fragmented distribution possibly implies great antiquity and parallels in part the similar fragmented distribution of other Mygalomorphae common to Australia and New Zealand notably *Hexathele* (sub-family Hexathelinae of Dipluridae) which is found right down eastern Australia, westward into S.A. and also in Tasmania; *Migas* (family Migidae) occurs in New Zealand and Tasmania but not mainland Australia; *Dyarcyops* (family Ctenizidae) ranges from New Guinea [two species at present included in *Arbanitis* (Rainbow 1920)], through eastern mountainous Australia to Tasmania and westward to S.A. It also occurs in New Zealand where its species are included in *Cantuaria* by Forster (1967) and in Forster and Wilton (1968).

(iv) The southern and essentially south-eastern distribution of *Stanwellia* (it has not been found north of Sydney and does not extend into Queensland) and its close relationship to the New Zealand genus *Aparua*, suggests an ancient origin. The possibility of affinities with South American and/or South African and Mascarene genera might profitably be looked for.

Deposition of Specimens

Types of earlier described species, specimens cited by previous authors, and various formerly unnamed specimens sighted by the present author are located in museums as listed above under the species. All new types (see species descriptions above) are being deposited in the Australian Museum, Sydncy, the National Museum, Melbourne and the South Australian Museum. The following specimens which have been cited in the text have been deposited in the Australian Museum; corresponding Museum register numbers are given in brackets after the author's numbers.

Stanwellia grisea (Hogg): BYM 65/11 (K69308), BYM 65/16 (K69306), BYM 65/27 (K69307), BYM 65/693 (K69305).

S. hoggi (Rainb.): ♂ specimen collected by R. Mascord (KA1).

S. nebulosa (Rainbow and Pulleine): BYM 55/727 (K69303), BYM 59/425 (K69304). *S. pexa* (Hickman): BYM 54/65 (K69309), BYM 54/66 (K69310), BYM 70/38 (a ♀ specimen collected by V. V. Hickman from Queen's Domain, Hobart) (K69312), BYM 70/36 (collected by V. V. Hickman from west coast Tasmania) (K69311). Unidentified *Stanwellia* specimens: BYM 59/404 (K69313), BYM 65/39 (K69314), BYM 65/41 (K69317), BYM 65/48 (K69315), BYM 65/677 (K69316), BYM 65/685 (K69318). All other specimens in the author's collection are lodged at the Zoology Department, University of Western Australia.

Acknowledgements

For the loan of types I wish to thank Dr. H. Weidner of the Zoological Museum, Hamburg, Dr. O. Kraus of the Natural History Museum, Frankfurt, Dr. J. Proszynski of the Institute of Zoology of the Polish Academy of Sciences. For making types and other collections available, for general help and offer of facilities, while visiting the respective museums, my thanks are extended to the following: Dr. G. O. Evans, K. H. Hyatt and the late D. J. Clark of the British Museum (Natural History); the staff of the Hope Museum, Oxford; the late A. Musgrave of the Australian Museum, Sydney, and H. Womersly and G. Grose of the South Australian Museum. Professor V. V. Hickman generously gave the author Tasmanian specimens and offered helpful information (in Litt.). Dr. J. Springett kindly donated some specimens. I very much appreciated helpful discussion on the relationships of diplurine spiders with R. A. Dunn, Honorary Arachnologist of the National Museum, Melbourne. For some transport in other states I must thank B. Malcolm, K. Main and M. J. Littlejohn. Some of the specimens on which this study is based were collected while the author was in receipt of a Research Grant from the University of Western Australia during 1952-1956. This grant also supported a visit in 1954 to the Australian Museum, in order to examine types. The Commonwealth Scientific and Industrial Research Organisation assisted with field and travel expenses during 1952-1954. A grant from the International Federation of University Women (Alice Hamilton Fellowship for 1958) supported a visit to the British Museum (Natural History) in order to study types of Australian spiders.

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13.—Mulga (North) Chondritic Meteorite Shower, Western Australia

by W. H. Cleverly*

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Abstract

Further recoveries in 1970 and 1971 of the stony meteorites Mulga (south), Billygoat Donga, and Mulga (north) demonstrate the partial overprintings of their strewnfields, though the sequence of arrival is uncertain. A total of 781 fusion-crusted stones or fragments of Mulga (north) of aggregate weight 19.5 kg have been recovered from an elliptical strewnfield of dimensions 6.1 x 1.2 kilometres. Detailed field records of the circumstances of occurrence and sites were maintained.

The degrees of entirety of the stones and stages of development of fusion crusts have been defined and are described for individual stones by a system of code letters; textures and minor features of the crusts are briefly noted. The stones stably oriented in flight have been nominated and the criteria used are stated. The sphericities of individual stones, their weights, and where possible the weights when restored to a fully primary crusted condition have been determined.

The degree of fragmentation does not appear to have been as great as for showers such as Holbrook. A complex series of aerial fragmentation events is indicated for Mulga (north) by the frequent occurrence of fusion crusts of various developmental stages on different facets of the one stone; re-assembled stones provide further evidence of the step-wise nature of the breakdown; the spalling of thin flakes from the surfaces also contributed. The applicability of the Gaudin relation to the size distribution has been examined, and an attempt made to isolate the products of the initial fragmentation for similar study.

The field distribution has been treated only qualitatively but a detailed tabulation of the surface features, weights, and morphology together with the co-ordinates of the sites of find of all pieces has been prepared as the basis for study of the field distribution and of the factors which could influence it.

Introduction

Details of the stony meteorites Billygoat Donga, Mulga (south), and Mulga (north), and of their recoveries during the period 1962-66 from a small area centred 95 km N.N.E. of Haig, Western Australia, are available in literature, but a brief summary is desirable before detailing the recent recoveries. In 1962, T. and P. Dimer found three small meteoritic stones close together about 11 km north of Billygoat (or Mulga) Donga, which is located ca. 30° 08′S., 126° 22′E. They lost two of the stones and the remaining one became known as Billygoat Donga (I). In 1963, the A. J. Carlisles Snr and Jnr. noted a shallow depression in the ground to the north of Billygoat Donga, and because it differed in some way from other natural features of the area, they suspected a meteorite crater, searched and found within it a 16 g fragment of stony meteorite. No petrographical examination of this stone was possible, but it was recorded as Billygoat Donga II. The stone was returned to the finders and was subsequently lost.

Late in 1963 the writer sought unsuccessfully the crater described by the Carlisles, but found instead three fitting fragments of stony meteorite which were initially recorded as Billygoat Donga III. In the following year he found five more fragments of the same type, and in extending the area of search found a concentration of 59 stones of distinctly different morphology. Subsequent petrographical examination confirmed the distinction, though both are olivine-bronzite chondrites with fayalite index 18, and simultaneously demonstrated that they were unrelated to Billygoat Donga I which is an olivine-hypersthene chondrite with fayalite index 25. Billygoat Donga III was re-named Mulga (south), and the concentration of 59 stones together with a further 12 found in 1966 was named Mulga (north). Billygoat Donga thus remained represented only by the small stone found by T. and P. Dimer (McCall and de Lacter 1965; Cleverly 1965; McCall 1968; McCall and Cleverly 1968).

The extended distribution of 13 more stones of Mulga (north) recovered during a brief visit in 1967 (bringing the total to 84) made it increasingly likely that the known material was but a fraction of a considerable shower. A field trip in December 1970 had as one of its principal objectives the collecting of Mulga (north) and the delineation of its field of occurrence. It was expected that search would be facilitated by minimal grass cover in the summer season, though climatic conditions might be extreme; both expectations were fully realised. In nine days, three searchers recovered 325 pieces of meteorite from within an elongate area of complex shape and of dimensions exceeding 4 x 1 kilometres. From their distinctive morphologies 321 pieces were recognised as Mulga (north) and 3 as Mulga (south). A single piece resembled the Billygoat Donga (I) stone which had been found about six kilometres further north eight years previously. In response to a request for determination of the fayalite index of the olivine, Dr. Brian Mason stated (pers.comm)—"a typical hypersthene chondrite with olivine composition Fa 25 . . . indistinguishable from Billygoat Donga; even the degree of weathering is the same". A triple overprinting of the strewnfields of these three meteorites had thus been demonstrated.

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When a detailed plot of these occurrences was prepared, it was realised that the gaps and apparent anomalies in the distribution of Mulga (north) might be only deficiencies in the data. A further field visit was therefore made in December, 1971 to concentrate search on gaps and critical areas. As the result of a dry year without seasonal growth of grass the ground

Figure 1.—View westward in the middle section of the strewnfield of Mulga (north) meteorite, about 95 km N.N.E. of Haig, Western Australia. Trees in left middle distance are in Three Mile Donga (see Fig. 2). Well-used vehicle track at right connects the main line of survey stations extending roughly along the axis of the strewnfield. Photographed in December, 1971.

surface was ideal for search (Fig. 1). The same three persons found 391 pieces of meteorite in $9\frac{1}{2}$ days, extending the strewnfield to a narrow ellipse of dimensions 6.1 x 1.2 km and of area 5.4 square kilometres. The recoveries included 13 pieces of Mulga (south), a fragment of Billygoat Donga fitting the stone found in 1970, and a small stone since named Mulga West. The position may now be summarised whilst referring to Figure 2.

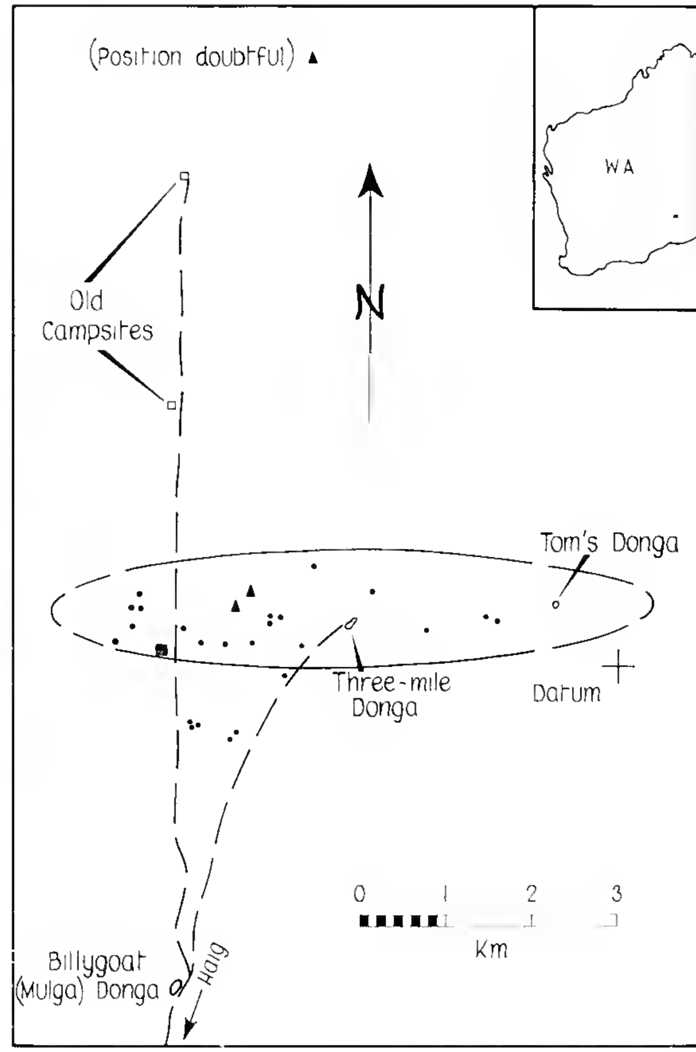

Figure 2.—Sketch map showing location of the approximately elliptical strewnfield of Mulga (north) stony meteorite in relation to Billygoat Donga, Western Australia. Sites of find of the Mulga (south) meteorite (dots), the Billygoat Donga meteorite (triangles), and the Mulga West meteorite (square symbol) illustrate the overprinting of their strewnfields. Coordinates of individual sites of find are measured relative to the datum indicated.

1. Mulga (north) is known by 781 pieces of total weight 19.5 kg and its strewnfield can be reasonably defined except at the ends. The direction of flight was eastward. Very small individuals comparable with the Pultusk and Holbrook "peas" may exist at the western end but extreme climatic conditions mitigated against their observation and recovery. A few individuals weigh less than one gram, the lightest 0.37 gram. It is likely that a few large stones are still in situ within and beyond the eastern end of the known strewnfield, and that some of them might be completely embedded. Limitations of time precluded a detailed walking search, and the heaviest stone (the easternmost), was recovered during a reconnaisance type search by vehicle on widely spaced grid lines; only two fifths of its vertical dimension was above ground surface.

2. The Mulga (south) meteorite is known by 24 pieces of which all except five have the typical morphology of the earlier known material, i.e. are fragments with discontinuous areas of dark, very thin, fusion crust. The other five have additionally some remnants of an older, smoothly curved, primary type surface. The total known weight is 894 grams. The extent of the strewnfield and direction of flight are not evident. The rather curious distribution shown in Fig. 2 is the result of detailed search within the strewnfield of Mulga (north) coupled with only the most casual search or none at all in most parts of the surrounding area.

3. The Billygoat Donga meteorite is known by three pieces of total weight 633 grams. The site of find of the original stone is known only very approximately. The other two pieces, which were found 230 m apart during different field visits, fit to form an almost complete, fusion-crusted individual of nearly 500 grams. The form of the strewnfield is unknown. Because the original stone was reported to be one of three small individuals found close together, and the later finds constitute a much heavier and apparently isolated individual, the general direction of flight might have been southerly.

4. The Mulga West meteorite is known by a single, small, almost brick-shaped stone of weight 169.2 g found near the western end of the Mulga (north) strewnfield (Fig. 2).

Note added Aug 10, 1972. Dr. G. J. H. McCall advises (pers. comm.) that Mulga West is of rare type and thus unrelated to the other three common chondrites. Four meteorites are therefore represented within the Mulga (north) strewnfield.

Mulga (north) is less weathered and is a later arrival on earth than Mulga (south) (McCall and Cleverly 1968). Billygoat Donga is also somewhat weathered but the few pieces known do not appear to be as deteriorated as some of the more recently recovered stones of Mulga (north). It might be the most recent arrival or intermediate in age. Comparisons are made difficult because Billygoat Donga is of a different petrological type to the other two. A comparison of the specific gravities of stones of comparable weights with the probable values for fresh meteorites (Table 1) is inconclusive.

All three meteorites are "finds" of common chondrites and their material value is relatively small, but all except 1 of the 809 pieces were found by persons of scientific training, and the maintenance of unusually complete records of the circumstances of occurrence and locations has been possible. These data are especially valuable for Mulga (north) and should provide a partial answer to the plea of Frost (1969) for such details.

It is surprising that after about 70 man-days have been spent in the area, the crater which was seen by the Carlisles in 1962 and which initially drew attention to the area, remains unrecognised. The Carlisles, with the accumulated knowledge of three generations and over half a century of familiarity with the Nullabor Plain are probably the best qualified of anybody to decide that a feature is unusual. Their unparalleled record as finders of meteorites (McCall and Cleverly 1970 Table 1) attests to the acute powers of observation they have needed to develop in this generally inhospitable region. Moreover, they have since, in 1966, recognised the impact crater of the Pannikin meteorite and collected small chips of stony meteorite from within it (McCall and Cleverly 1968). With the advantage of hindsight, the Billygoat Donga II stone from the crater resembled Mulga (north), but it is difficult to believe that a crater-like feature of the order of 10 m diameter could have escaped notice within the known strewnfield.

A by-product of the search was the recovery of 102 australites (tektites), or about 19/square kilometre. Their total weight is 127 grams. Nearly all are fragments and several are clearly artefacts; all five of those selected for expert examination were confirmed as artefacts by C. E. Dortch (pers. comm.). Such artefacts were evidently discarded by itinerants or date from times of more humid climate because present sources of water are ephemeral. An occasional clay-floored donga* such as Billygoat Donga could hold shallow water only very briefly; no rock holes of significant water capacity are known in the area.

Mulga (north) meteorite

Reference will be made in the balance of this paper to Table 2 which, as reproduced, contains only those stones specifically referred to in the text and a few others illustrating types. It is neither practicable nor necessary to reproduce the full table of 781 items which is of interest principally to the specialist student of the mathematics of fragmentation and distribution. A copy of the full table is available on application to the Director, Western Australian Museum, Perth, Western Australia.

* The term donga is used on the Nullarbor Plain for shallow, sometimes extensive, sink features of the limestone surface. Many dongas contain growths of trees (Fig. 1), and being campsites favoured by itinerants, are often named by them, though few such names have official recognition.

Table 1.

Comparison between specific gravities of meteorites as found and values of unweathered types

Meteorite and Type	Specific gravities of pieces in weight range 90–145 grams	Weighted mean of preceding column	Range of specific gravity for unweathered meteorites of same type (Mason 1962)	Range of mean weathering effect (Col. 4 minus Col. 3) and maximum individual effect
Mulga (south) CBr	3.333, 3.364	3.35	3.6—3.8	0.25 to 0.45 0.47
Billygoat Donga CHy	3.380, 3.434	3.41	3.5—3.6	0.09 to 0.19 0.22
Mulga (north) CBr	3.590, 3.600, 3.608, 3.605, 3.602, 3.612, 3.604, 3.585	3.60	3.6—3.8	0.00 to 0.20 0.21

Table 2.

Field numbers, classification, weights, orientation, sphericity, and coordinates of sites of find for some stones of Mulga (north) meteorite

Field number	Classification	Weight g	Weight as CP g	Orientation	Sphericity	Westing km	Northing km
3	FPU	77.4	....	....	0.70	3.76	0.61
27	CP	73.6	73.6	X	0.75	3.18	0.72
33	CPT	111.3	129.3	X	0.51	3.57	0.58
65	CPS	27.3	....	....	0.69	3.84	0.85
111	DPTU	336.4	340.1	X	0.78	2.75	0.91
118	CPS	87.3	....	X	0.61	3.04	0.45
128	CPS	169.1	....	X	0.69	2.15	0.49
135	CPT	22.9	....	....	0.60	3.21	0.39
139	FPUT	23.8	....	....	0.63	2.27	0.60
140	FTPU	4.7	....	....	0.78	2.28	0.61
141	CTP	4.2	....	....	0.53	2.28	0.60
146	CPT	22.1	....	....	0.42	3.93	0.78
149	FPTSU	99.1	....	....	0.51	2.89	0.44
150	DPSTU	58.9	....	....	0.71	2.91	0.43
155	FPUT	151.3	....	....	0.63	4.10	0.98
159	CPT	0.5	....	....	0.48	2.20	0.84
164	CP	205.9	205.9	X	0.75	2.13	0.64
167	CP	188.1	188.1	X	0.69	1.88	0.77
174	CPT	60.0	61.5	....	0.69	3.51	0.37
176	FSUTP	56.4	....	....	0.53	3.52	0.40
199	FPSU	44.9	....	....	0.62	3.80	0.92
208	CTSP	188.3	....	....	0.73	1.55	0.56
209	CTSP	245.7	....	....	0.83	1.42	0.62
218	CPST	14.5	16.3	X	0.68	4.22	0.71
245	CPT	4.8	4.8	X	0.57	4.81	0.71
260	CPS	7.2	7.2	X	0.71	4.98	0.58
309	CPST	5.0	5.0	X	0.69	5.06	0.65
321	CP	0.4	0.4	....	0.75	5.11	0.60
390	FPTU	4.8	....	....	0.72	5.47	0.52
448	DPU	0.4	0.4	....	0.60	5.64	0.56
469	CPT	5.5	....	....	0.51	4.63	0.29
473	DPTU	2.6	3.0	....	0.88	4.62	0.52
499	FPU	64.7	....	....	0.66	3.59	0.71
533	CPT	347.9	371.0	....	0.66	2.15	0.35
542	CP	533.4	533.4	....	0.77	2.06	0.73
638	CPT	8.7	9.3	X	0.61	5.25	0.88
677	CPT	64.7	64.9	X	0.66	3.79	0.19
758	CP	4.9	4.9	X	0.67	5.19	0.75
807	DPU	2095	2110	....	0.68	0.05	0.60
822	CPT	2.5	2.5	....	0.63	4.94	0.47

Field occurrence

Stones are identified in Table 2 by their field numbers (column 1). Most of the numbers missing from the full table are accountable either to other meteorites or to spurious material. In the field, fragments showing some degree of weathering and separated by distances of up to one or two tens of centimetres were regarded as products of disintegration and were recorded as a single stone. Likewise, when two or three fitting stones not showing advanced weathering were found up to a few metres apart, they were accepted as impact fragments and recorded as one stone; the situation was especially clear when such a group was found relatively isolated from other stones. As a result of this recording procedure, both the number of stones and the amount of uncrusted meteorite surface attributable to impact or weathering have been minimised.

More than 90% of the stones lay on the surface of the ground or were embedded only to the extent of inequalities of the contacting surfaces. The remainder were embedded from one quarter to (rarely) as much as three quarters of their vertical dimension, and of those so embedded many are judged to have been oriented stones in flight position. The general shallowness of the embedding and some of the other features—such as the infrequent occurrence of regmaglypts—result from the generally small size of the stones.

The survey of the strewnfield was made by prismatic compass and pacing, a method adopted initially of necessity because the writer was unaccompanied when the first 59 stones were found. Use of this procedure continued during later field trips because atmospheric refraction effects restrict so severely the times of the day when instruments can be used, and because the

opportunities for field work in this area are very limited. The two original survey stations were supplemented during later searches to form a chain of 16 stations with a branch line of one or two stations to each side of the main line where required. From these stations all sites were paced in. The speedometer reading for a vehicle traverse along the main line of stations, after adjustment for known error, differed from the plotted length by 3%. A large overall error is therefore unlikely, and because the pacing was done by the same person on all five occasions, internal distances should be in proportion and any errors of the same order.

Co-ordinates of individual sites of find (last two columns of Table 2) are westings and northings in kilometres from an arbitrary datum located 0.05 km east of the easternmost site (the heaviest stone) and 0.05 km south of the southernmost site (see Fig. 2). Because the axis of the strewnfield is approximately west-east and the direction of flight was eastward, the westings are in the form which has become conventional for the mathematical description of lateral distribution, while the northings are an expression of the distribution transverse to the axis. Co-ordinates have been rounded to the second decimal place (the nearest 10 m) and as a result of this, a few pairs of sites have identical co-ordinates.

It is believed that the stones were found close to their original points of fall. Ground slopes are generally very low and, to judge by the insignificant drift of weathering fragments from their parent stones, the amount of movement of the stones is likely to have been very small. The aboriginal inhabitants appear to have made no use of the stones.

Features of individual stones

Stones generally have the angular, faceted yet smooth form which results from fragmentation followed by development of fusion crust, but many stones also have surfaces free of crust or thinly veiled by crust.

The degree of entirety of the stones, the stage of development of the fusion crust(s), and the relative areal abundances of the crust types are indicated by a system of code letters in column 2 of Table 2.

The degree of entirety is expressed by either C, D or F. C denotes completely fusion-crusted stones, irrespective of the degree of development of the crust(s). D indicates stones with one, or occasionally more than one surface lacking crust, and having a profile such that a probable reconstruction to fully crusted form can be made. This type of stone is generally much more than 50% of the mass of the original but lacks a "cap piece" or "edge piece". F indicates fragments with at least one surface free of crust and whose profile does not allow a confident reconstruction of the shape; some of these are the type of fragment lacking from category D stones.

The degrees of development of crust are indicated by P, S, and T. P indicates the primary crust of smoothly curved surfaces from which all except centimetre-sized inequalities have been smoothed out. It is close-textured or knobby, except for localised developments of scoriaceous or striated texture, particularly on stones which were stably oriented in flight (for textural terms see Krinov 1960). S denotes surfaces of the second kind ranging from finely rippled surfaces with crusts which barely veil the roughness of the fracture to coarsely wavy surfaces which are not always clearly distinguishable from primary crust, though the distinction is easily made when the two types occur on different facets of the one stone. These crusts do not commonly develop knobby texture, presumably because some minimal degree of development is necessary before the superior refractoriness of disseminated metallic grains can be expressed in that way. T denotes tertiary crusts covering the developmental range:—"smoking" of the surface, discontinuous films with mineral visible through gaps or through the crust, films through which mineral is only occasionally seen, complete crust which fails to hide the roughness of the surface and has an almost hackly appearance. Beyond this stage is the finely rippled crust of the secondary type. The nomenclature is similar to that of Foote (1912) for the Holbrook shower except that the hackly type is here placed in the tertiary category.

In very numerous cases the creep of crust over the edge of a later fracture surface indicates that a tertiary crust should be sought and that, even if such a crust is not detected, the surface must have been produced by aerial fragmentation. The creep of fusion crust is sometimes observed in the direction away from the surface of lesser crust development, e.g. from tertiary over primary surface on stone No. 99. This results from the adoption of an appropriately oriented flight position following the later fragmentation.

The letters P, S and T may be applied to different facets of the one stone representing surfaces produced by successively later fragmentation events or surfaces developed simultaneously on facets of an oriented stone enjoying different degrees of protection during atmospheric flight.

The system is admittedly subjective but a degree of sureness is developed by familiarity with the material. During second and subsequent re-examinations, most of the surfaces initially classified as doubtful could be classified with confidence. It is important to appreciate that even if the surface types were classified perfectly, there would be no implication that the surfaces of a given (say, secondary) type had developed following the same fragmentation event; rather, they are surfaces which have been exposed to similar sets of conditions possibly as the result of quite a number of different events.

U indicates uncrusted surfaces. By definition this letter cannot occur in combination with C and must occur with D or F. It might therefore appear unnecessary but it is required for the

following purpose. During a final review of the material the letters P, S, T and U were arranged in sequence of decreasing surface area. Each of the three types C, DU and FU can occur in seven combinations with crust types, e.g. CP, CS, CT, CPS, CPT, CST, CPST, but with the permutations arising from surface abundances the number of possible expressions is considerably increased. About 40 different expressions have been used.

Regmaglypts, usually shallow and of small size (1-2 cm) are sparsely present on only about 3% of the pieces, usually stones of weights exceeding 100 g or fragments which have clearly been derived from the larger stones.

Most stones show surface cracking ranging from single cracks to a complete breadcrust pattern initiated during the cooling of the surface in the later stages of atmospheric flight. A gaping breadcrust pattern occurs seldom, usually on the weathered and swollen underpart of a stone which has been embedded in the ground.

Because shape factors almost certainly affect the distribution, it is desirable that they be quantified, but such factors are difficult to assess. Stones which are stably oriented in flight can be expected to fly more truly and further than those which tumble and to be less affected by transverse winds. Much the same is probably true of stones whose shape approaches the equidimensional compared with those of comparable weights which are tabular or otherwise inequidimensional.

A stable flight orientation (shown by X in column 5 of Table 2) is indicated by the presence of one or more of the following criteria:—

1. Roughly conical, pyramidal or wedged shapes embedded with point or edge down. Though the views illustrated in Fig. 3 have considerable similarity, they represent a wide variety of three-dimensional shapes. No. 111 (Fig. 3A) is representative of the conical and pyramidal stones; No. 128 (Fig. 3D) is a split pyramid which has developed secondary crust on the broken surface; No. 33 (Fig. 3E) is a roughly tabular stone which, despite losses and development of tertiary crusts, appears also to have been oriented in flight; No. 167 (Fig. 3F) is typical of a variety of stones with lozenge-shaped sections; it is roughly triangular with point down in the third (unillustrated) dimension; others with this type of section include more elongate and hence prismatic stones, which evidently had a leading edge in flight (e.g. No. 118). This criterion was not accepted as sufficient in itself because exceptions almost certainly occur. For example, the relatively thin, triangular No. 499 was embedded with the sharpest angle of the triangle downward, but such is an unnatural orientation for a stone having so much surface. No. 164 is oval in plan view, lozenge-shaped in section, and embedded in the

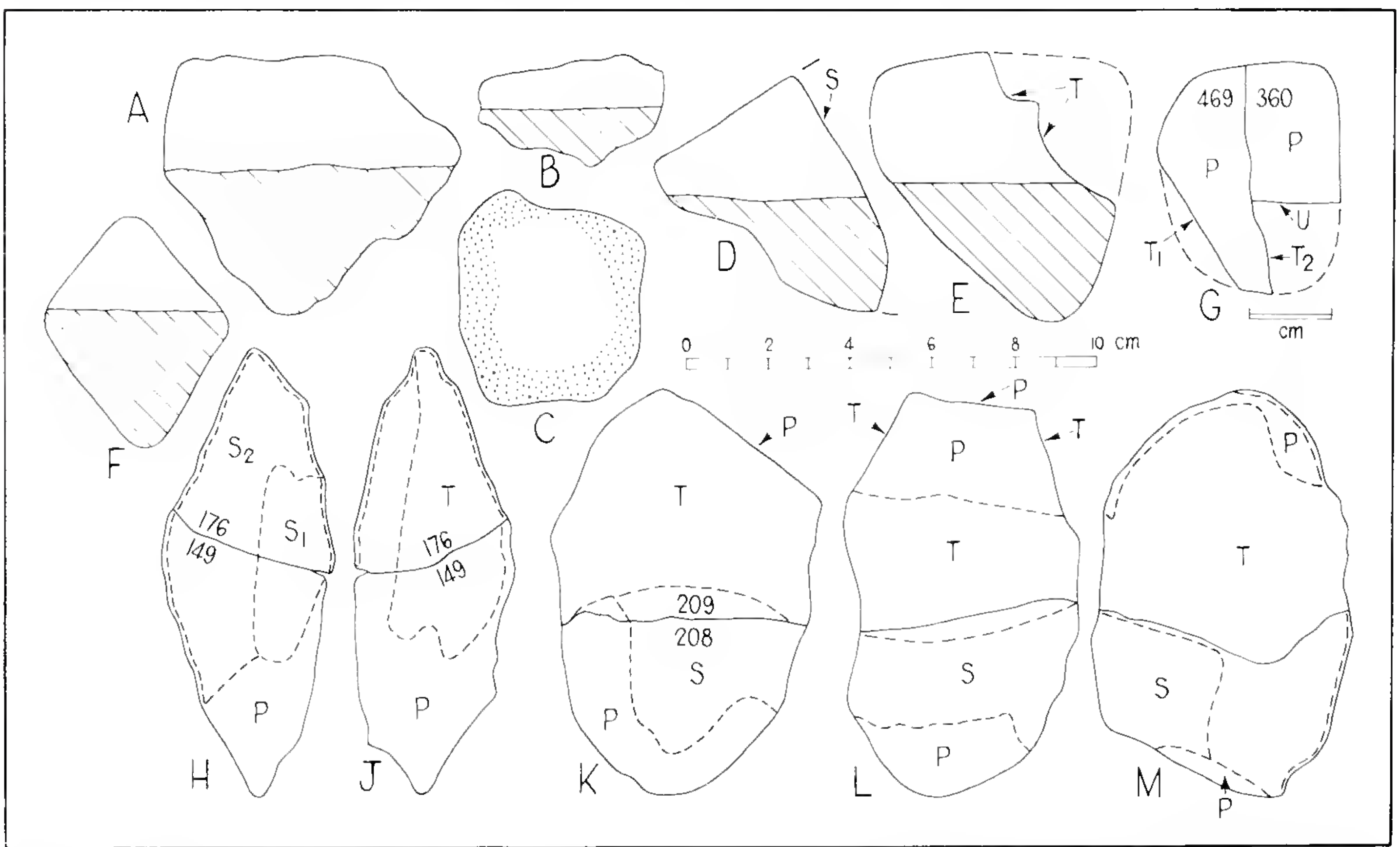

Figure 3.—Sketches of Mulga (north) meteoritic stones. A.—Profile of No. 111 showing soil line, embedded portion shaded. B.—As for A, No. 677. C.—Base of No. 677 showing encroachment of scoriaceous crust from the sides. D.—As for A, No. 128. E.—As for A, No. 33. F.—As for A, No. 167. G.—Composite stone 390/469, restored parts indicated by broken lines, surface types lettered as in text. H. and J.—Two views of composite stone 149/176 showing surface types. K. to M.—Three views of composite stone 208/209, which is roughly triangular in midsection, showing surface types. The scale applies to all except G, for which a one-centimetre bar is shown.

manner of Fig. 3F, but the best-developed regmaglypts are on the surface found uppermost; it was probably oriented in flight but not in the position as found.

2. Regmaglypts of appropriate distribution, elongation, or alignment. The almost cuboidal No. 542 is shown to have been oriented by the regmaglypts and the distribution of scoriaceous crust rather than by its being embedded "edge on".

3. Textural types characteristic of frontal, lateral, and rear surfaces with appropriate distribution (Krinov 1960). In particular, small areas of scoriaceous crust to one side of surface irregularities or as a rim encroaching on one facet of a stone are common. Thus the flatly pyramidal stone No. 677 has regmaglypts on the front and a scoriaceous zone 5-10 mm wide rimming the flat base (Fig. 3 B, C). Examples of more sharply defined scoriaceous borders are on the bases of the flatly conical No. 758 and the almost tabular No. 638. It is necessary to distinguish this creep of crust from the much more general case when the stone was tumbling in flight. The regular width, and hence the apparently sharp edge of the overflowed crust on oriented stones is usually diagnostic. The striated texture (thin streams of melt glass) is occasionally detectable as a radial pattern on the apices of conical stones or over their lateral edges. Spattered droplets on the lee side of high points, as in the case of scoriaceous crust, occasionally provide additional evidence.

4. The combination of a primary crust with one of lesser development on a significant facet such as the base of a cone. Because there are other possible interpretations, such stones were not accepted as oriented without confirmatory evidence.

From a consideration of the above criteria 116 stones have been nominated as oriented during at least some part of their atmospheric flight. On a further 27 stones the evidence was less convincing. The oriented stones comprise at least three classes; firstly, those of category CP; secondly, those whose orientation during the earlier stage of flight preceding a secondary fragmentation is indicated by regular but incomplete rims of scoriaceous crust terminated abruptly against facets of lesser crust development; thirdly, those which were oriented only after a secondary fragmentation as is shown convincingly in several cases by rims of crust and patches of scoria directed away from surfaces of lesser crust development on to secondary or primary crust. A fourth class of stones which were oriented before fragmentation and re-oriented afterwards is doubtfully represented by two examples.

The various expressions of sphericity used in sedimentary petrology (Pettijohn 1957) describe with varying degrees of success, the approach to spherical shape, i.e. to minimal surface area per unit volume. None of these expressions is highly satisfactory for angular fragments of low roundness. Thus when applying the Zingg system to angular objects the manner of taking the dimensions may require measurements between diagonally opposite corners or obliquely inclined edges. Following are the results of measuring 100 Mulga (north) stones by this method:—

Class I (tablets)	27
Class II (equidimensional)	53
Class III (prisms)	4
Class IV (blades)	16

Because the tabular specimens are partly accountable to flat "cap pieces" and to surface spalls, it is likely that the principal fragmentations yielded fragments amongst which "equidimensional" shapes considerably outnumbered the others combined. Twelve of the sixteen CP stones included in the above sample belong to Class II.

The method used to determine the sphericities recorded in column 6 of Table 2 was the ratio d_1/d_2 where d_1 is the diameter of the sphere of equivalent weight (calculated from weight and density), and d_2 is the diameter of the circumscribing sphere. The method has the merit of simplicity but does not distinguish between the broad classes of inequidimensional shape. Further, the largest dimension is not uncommonly smaller than the diameter of the circumscribing sphere, a situation which arises also, though in the writer's experience not as frequently, in materials which have suffered some rounding by terrestrial erosion.

The spericity values range from 0.42 to 0.88 but only 11 stones have values less than 0.5 and only a further 11 have values greater than 0.8. The mean value is 0.62. As had been anticipated, the mean sphericity value for stones of category CP is distinctly higher, being nearly 0.70.

Most of the common crust types and minor surface features have been mentioned inter alia above, and may now be summarised together with some rarer features. Knobby and close textured crusts predominate; scoriaceous texture is of common occurrence but very limited in area on any one stone; the striated texture is uncommon and the net texture comprising two sets of crossing striae is rare; only a single good example of porous texture was observed occurring centrally to a rim of scoriaceous crust on the rear surface of an oriented stone, an unusual location. Spattered droplets of glass occur but not in the abundance and size which constitutes warty texture, probably because of the generally small size of the stones. Surprisingly for a meteorite with a pronounced degree of recrystallization (McCall and Cleverly 1968), chondrules are not uncommonly visible in the fusion crusts as rounded and more lustrous patches—the so-called "oily stains"—and they sometimes show some detail of their internal constitution. A good example is the large (nearly 5 mm) barred chondrule visible in the primary crust of stone No. 27.

The weights of the stones (column 3 of Table 2) range from 0.2 g to 2095 g with frequency as follows:

>1000g	1
1000 to 100.1 g	31
100 to 10.1 g	253
10 to 1.1 g	442
1 to 0.2 g	54

Column 4 of Table 2 shows the weight of the stone when restored to category CP for a purpose explained in the next section. Such restorations are not possible for stones of category F, nor generally possible for any stone which does not have primary crust as the most abundant surface type, i.e. has P as the second letter in the classification. Estimates become increasingly hazardous if more than two surface types are present. In practice, estimates could be made for some of the stones of categories CPS, CPT, DPU, DPSU, DPTU, and rarely for others. Estimates were made by completing the form with modelling clay, weighing the clay and applying a factor to correct its weight to that of meteorite. When completing the shape, advantage was taken of the observation that most of the meteorite surfaces are flat or convex; when concave, they are usually only gently so. The weight of restored material was generally less than 10% of the weight of any individual and is collectively only 3% of the weight of all restored stones.

Fragmentation

If the pieces of Mulga (north) of mean weight 25 g were derived from a single mass of more than 19.5 kg, aerial fragmentation was clearly a highly effective process. However, for the Holbrook shower (Foote 1912; Nininger and Nininger 1950) the mean weight of the known fragments is less than 14 g though the total weight is 235 kilograms. From the mathematical estimates of the number of fragments and total mass of the Pultusk shower (Lang and Kowalski 1971) the mean fragment weight would be about 11 g for an estimated mass of two metric tons (the known material has only about one tenth of that weight).

Mean weights, at best, are an inadequate basis for comparison and there are also enormous differences in the efficiencies of collection of these showers. Foote (op.cit.) employed more than 100 people for two months in collecting Holbrook and he was followed after an interval of some years by the highly organized parties of Dr. Nininger, who made several visits; scarcely 1% of that time has been spent upon collecting Mulga (north), though the dimensions of the two strewnfields (and also that of Pultusk) are of the same order of size (Krinov 1960). The degree of fragmentation of Mulga (north) may therefore appear to have been considerably exceeded in other showers but an intensive collecting campaign might well lead to a reassessment. At least until a change in seasonal conditions brings itinerant workers to the Billygoat Donga area, the site of Mulga (north) is almost inviolable.

Amongst "finds" of meteorite showers, only Plainview is superior to Mulga (north) both numerically and in total mass, but the Plainview stones are of a distinctly larger order of size.

A consideration of the fusion crust types on Mulga (north) stones shows that series of fragmentation events were necessary for the reduction of the material to such a small average size. Individual stones weighing only one or two tens of grams may show on different facets the whole series of surface types (P, S, T, U), and the tertiary crusts may show distinctly different developmental stages on facets of the one stone. Stones which have been re-assembled from separated pieces warrant description in some detail because they are informative both as to the reduction process and the field distribution.

Pieces Nos. 3 and 199 (for details see Table 2) were found more than 300 m apart (Fig. 4). They fit together on uncrusted surface and the composite stone has classification CPS. No. 65 fits approximately upon the secondary surface (a close fit is not to be expected when opposing surfaces have each attained the rippled secondary stage of development). The fully re-assembled stone has classification CP. It appears therefore that following the initial fragmentation, a piece which weighed rather more than 150 g and which was developing primary crust, lost one end. The surfaces thus exposed ultimately developed secondary crust. At a distinctly later stage of flight, the larger piece broke across.

The pieces Nos. 149 and 176 fit together on uncrusted or thinly tertiary-crusted surfaces (Fig. 3 H, J). The composite stone has primary crust at both ends, but large scars with secondary and tertiary crusts transgress the line of join. The original fragmentation thus yielded a mass which acquired primary crust and this was followed on at least two separate occasions by losses of flat slabs from the sides; finally the remnant broke across. The composite 208/209 (Fig. 3K-M) has a similar but more complex history, having primary crust at the ends with secondary and tertiary crusts of various developmental stages in a central girdle representing losses at various stages prior to the final breakage.

Specimen No. 390 fits No. 469 on part of the tertiary surface (Fig. 3G). The composite has classification DPTU, the weight as CP can be estimated reliably, and the history reconstructed. A tabular stone weighing about 14 g first lost a corner piece weighing about 1.8 g (not recovered); the scar has well developed tertiary crust (T_1). Distinctly later, the main piece broke across and the edges of the break show creep of crust over the edge of the fracture surface (T_2). No. 469 is one of the two pieces, but the other piece broke again and its larger fragment is No. 390; the smaller fragment of weight ca. 1.7 g was not recovered.

Specimen No. 533 has a shallow scar on one face on which No. 135 fits perfectly to form a low bulge above the surface and to make an almost complete stone. Complementary parts of the contacting surfaces show strong shearing. Possibly as a result of surface heating the upstanding portion burst out of the surface of the parent mass which was subsequently found more than one kilometre to the east of it (Fig. 4).

For simplicity in the above accounts, the development of primary or other crusts has been recounted as if each was a distinct episode; in fact, the further development of the primary crust continued simultaneously with the development of secondary and tertiary crusts on more newly exposed surfaces.

It is remarkable that pieces as light as 14 g should break and break yet again. Loss of "spalls" from the surfaces was also an important mechanism contributing to the break-down. Stones as light as 2 g show circular or ovoid scars of a few millimetres dimensions resulting from such losses. Often the losses are no more than small patches of crust. The scars are commonly partially healed by tertiary crusts. The weight of material necessary for the restoration of such scars is often insufficient to affect the weight of the stone to the nearest 0.1 g (e.g. No. 822).

Metallurgical studies of comminution include experimental investigations of the influence of the impact velocity and other variables upon such features as the reduction ratio, fragment shapes, and size distribution of the products. It would be of interest to examine the Mulga (north) material in the light of such experimental results, but comparisons are hindered by the complexities and uncertainties of meteorite fragmentation processes. The writer subscribes to the general concept that a meteorite entering the atmosphere at cosmic velocity builds up in front of it a shock wave of heated and increasingly compressed air, and that with a sufficient velocity maintained to a sufficiently low altitude (i.e. air density) the meteorite shatters itself against this self-generated barrier. The calculations of Levin (quoted by Krinov 1960 p. 75) suggest that the air pressures generated could attain the static crushing strength of common rocks. Some writers have given prominence to heat stresses, but in view of the demonstrably shallow penetration of heat effects, fragmentation from this cause is likely to be confined to the loss of thin flakes and perhaps occasionally to a more complete fragmentation triggered by such losses. These general concepts apply to oriented stones (and conceivably also to a stone which happened to be rotating about an axis parallel to the line of flight), but such stones are a minority. In the more general case of stones rotating about any other axis or tumbling irregularly, the form of the shock wave and the direction of compression relative to the stone are continually changing. The situation of the meteorite may be compared with that of a ball compressed between a board and a table top, and forced to roll by movements of the board, movements which need not be constant either in speed or direction. Krinov (op.cit.) has drawn attention to the importance in the fragmentation process of these sharp variations in pressure on different parts of the meteorite.

The experimental work of Charles (1956) may be taken as an example of the difficulty of applying experimental results to a meteorite. Charles showed that for brittle material, equiaxial fragment shapes were favoured by high impact velocity. However, even the "low" velocity of his experiments involved impact times of only a few milliseconds. If the shattering of a meteorite involves the slow building up of pressure over a period of seconds or tens of seconds this is an exceedingly "low" velocity in the sense of the experiment. On the other hand, if a meteorite is tumbling rapidly, it might well be that even the "high" velocity conditions with exceedingly short impact times are encountered by a meteorite during atmospheric flight.

Not the least of the advantages of the controlled experiment is that the test piece may be shattered by a single blow and the fragments examined. They frequently contain secondary i.e. internal, non-bounding fractures. A meteorite fragment containing secondary fractures will presumably have a much reduced crushing strength and be especially liable to further failure, perhaps only momentarily later when it adopts a suitable orientation. When fragmentations are separated by very short time intervals, it is not possible to distinguish between the products of the two events. Thus the application to meteorites of even the well established relationships of size distribution of products is also complicated by uncertainties.

The method and nomenclature of Frost (1969) will be followed in the treatment of size distribution. A Gaudin population of sizes resulting from high speed impact is described by the relation

$$y = 100 \ (x/K)^m$$

where y is the cumulative weight percent finer than size x, and K and m are constants for any one population. For distributions of this type, the graph of log y against log x or against x expressed in phi units (i.e. $-\log_2 d$, where d is diameter in mm) will be a straight line with K

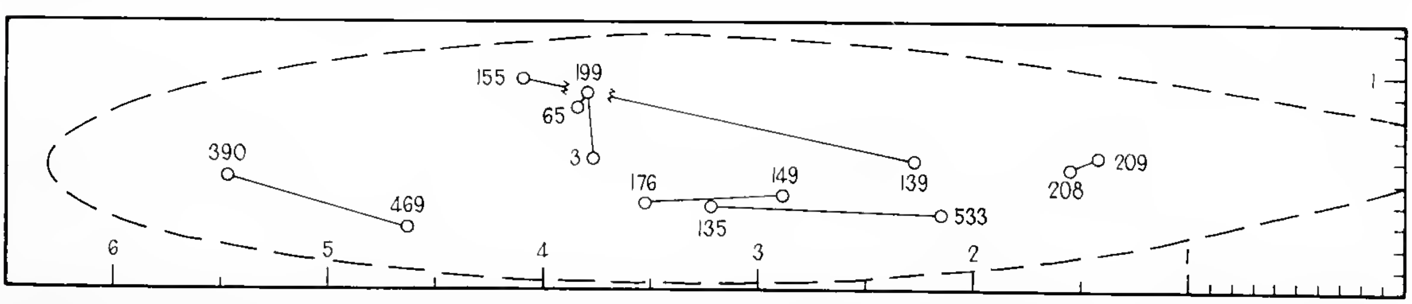

Figure 4.—Distribution of some fitting fragments (linked by lines) of the Mulga (north) meteorite, constituting partial minor distributions within the general stewnfield. Numbers along the lower and right-hand edges are kilometres west and north respectively of datum.

the maximum size and m a measure of the slope or sorting. Size is conveniently expressed in terms of an equivalent sphere. It may be deduced from the Gaudin equation that

$$d = -3.024 - 1.1073 \log_{10} M$$

where d is the diameter of an equivalent sphere in phi units and M is the mass of the stone in grams; the constant embodies the special case of the Mulga (north) shower, for which a density of 3.6 g/cm^3 has been used. Badly weathered material on the one hand and the freshest material on the other might differ by as much as 0.1 g/cm^3 from the adopted mean density figure, but the result is generally affected by only about ± 0.01 phi unit.

Frost (op.cit.) has concluded that a first estimate of 0.5 for m for both meteoritic stones and irons is not unreasonable, and the value 0.5 will be used here in order that results are on a comparable basis. In fact, an estimate of m for Mulga (north) gives a somewhat lower value, though it is well within the range found by experiment.

Figure 5A is a simple frequency diagram for the numbers of stones of Mulga (north) falling within intervals of half a phi unit. Disregarding stones smaller than -3½ phi units (of weight less than 2.7g) and those larger than -6 phi units (weight greater than 500 g), both of which groups are probably inadequately collected, there remain five points of reasonable reliability on the diagram. The line of best fit for these points applied to the Gaudin distribution leads to an estimate for m of about 0.4.

Cumulative size distribution curves are shown in Fig. 5B. Curve No. 1, which was prepared when only 405 stones were known, has a steepness comparable with the curves figured by Dr. Frost, but with a greater regularity than most of them arising from the large numerical size of the sample. Assuming that m has a value of 0.5 and that departure of the curve from the straight line representing Gaudin distribution is related solely to non-recovery of fine material the non-recovery of Gaudin-distributed small stones may be calculated. From the ten percent ordinate, the non-recovery is (54-10) 100/(100-10), or about 49%.

Curve 2 of Fig. 5B represents the 781 pieces presently known, and shows the distinct improvement resulting from the additional collecting. The upper portion approaches the Gaudin distribution with slope 0.5 as shown by the straight line; the non-recovery figure on the same basis is only 34%. Considering that only the 13 largest stones of Mulga (north) attain the size of the smallest material graphed by Dr. Frost for showers such as Tenham, these results appear highly gratifying, but the comparison is not strictly valid. It is noted that the material of those showers generally showed only one or two of the surface types designated in this paper by P, S, T and U, and therefore they were not the products of a series of fragmentation events.

It would afford a more valid basis for comparison if the products of a single fragmentation of Mulga (north) could be singled out. This has

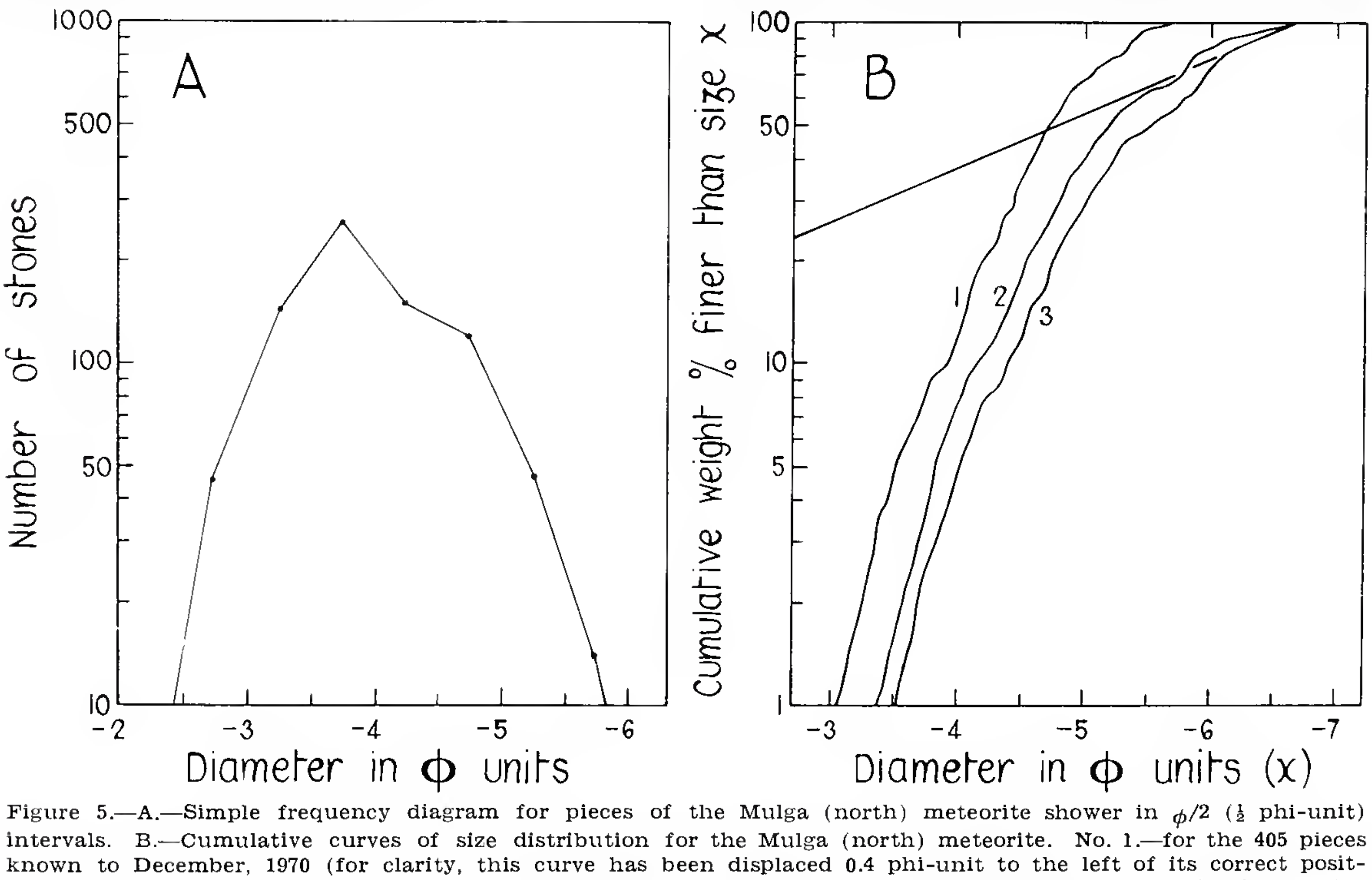

Figure 5.—A.—Simple frequency diagram for pieces of the Mulga (north) meteorite shower in $\phi/2$ (½ phi-unit) intervals. B.—Cumulative curves of size distribution for the Mulga (north) meteorite. No. 1.—for the 405 pieces known to December, 1970 (for clarity, this curve has been displaced 0.4 phi-unit to the left of its correct position); No. 2.—for all 781 pieces known to December, 1971; No. 3.—for pieces resulting from the initial fragmentation. The straight line is the Gaudin distribution of slope 0.5 positioned appropriately to curve No.2.

been attempted for the initial fragmentation, but rather sweeping assumptions are necessary —viz. that a single stone entered the earth's atmosphere, that the products of its initial fragmentation were capable of developing fully a primary crust, and that the products of later fragmentations were incapable of developing such crust on the newly exposed surfaces. Stones which would then qualify for inclusion in the sample are:—

1. Stones classed as CP.
2. Stones which can be restored to class CP, using diameters equivalent to the restored condition.
3. A few oriented stones of category CPS or similar, for which the surface of lesser crust development has been accepted as the result of sheltered location rather than of late exposure. Such stones may be identified in Table 2 by the weights and restored weights being identical.
4. Composite stones formed by uniting pieces found separated in the strewnfield, with or without restoration. Only three examples, one of which has a marginally acceptable degree of restoration, qualify for inclusion in this group.

Consideration was given to inclusion in the sample of small stones of inequidimensional shape of categories such as CPS. The doubt was that light stones of such shapes could maintain a sufficient velocity to develop fully a primary crust. However, the tabular pieces which are the majority of the group, might be only surface spalls from larger stones and the decision to exclude this small group cannot affect the cumulative weight curve significantly.

The acceptable groups comprise only 41% of the stones but nearly 60% of the mass, of which 1% is restored material. Twenty of the thirty heaviest stones belong to one or other of the first two groups. The mean weight of stones in the sample is 36 g compared with a mean weight for all stones of 25 grams.

Curve 3 of Fig. 5B thus purports to represent a sample of the products of a single fragmentation event. It is slightly steeper than curve 2 which represents all stones. The non-recovery figure on the same basis is 38% as against 34%. This slightly greater steepness is in accord with experimental experience (Gaudin and Hukki 1944), but the major problems of recovery of material and isolation of the sample from other products do not arise under controlled experimental conditions. Curve 3 is rather flatter than those figured by Frost (1969 Fig. 2), with which, if the exercise had been successful, a comparison would now be valid, but there is good reason to believe that it is not. For the sample to be fully satisfactory, it is desirable that only the largest products of the initial fragmentation should have been removed by secondary and later fragmentations. The removal of only the largest products from a Gaudin-distributed population of sizes does not affect the slope of the line but simply displaces it towards the smaller sizes. Clearly, the reassembled stones considered above range down to quite small size and none of them even approaches the size of the largest stone recovered. A portion of the sample with unknown size distribution has therefore been removed by the later events. The difficulty might be resolved by completely reassembling all broken material, but despite repeated trials, the reassembled stones constitute but an insignificant fraction of it. Though the isolation of a sample of products of the initial fragmentation might have been successful, it cannot be claimed that the sample is thoroughly satisfactory for use in this way.

The curves 1 to 3 of Fig. 5B were commenced from the relatively low 1% level because of the large number of small pieces known. Curve 2 is not greatly steeper in the 0.1%-1.0% range than in the 1%-10% range (it requires 36 stones to attain the 0.1% level). It is likely that the lower portions of these curves would not be significantly flattened by further collecting because there is no real difference between the lower parts of curves 1 and 2. There would be difficulty in detecting smaller material, particularly when it might be widely dispersed by atmospheric winds and weathered. It would be doubtfully advantageous to collect in the more genial winter season because past experience has been that the area is usually densely covered by tufted grasses of knee height or higher.

Field Distribution

Only qualitative and semi-quantitative observations are offered.

A simple conception of an elliptical strewnfield is that fragmentation during oblique approach results in an expanding cone of pieces which therefore meet the earth's surface in an elliptical area. The combined effects of gravity and air resistance, invariably present, result in some grading in the direction of flight, heavier fragments in general travelling further whilst light ones are more readily drawn into the vertical with free fall velocities. Other factors such as atmospheric winds also affect the distribution. Shape factors can be expected to have an influence, including the degree to which winds can affect the distribution. Of particular interest in the case of Mulga (north) are the effects of multiple fragmentation events. These later events at somewhat lower levels and steeper angles of approach can be expected to yield smaller and more equidimensional ellipses with less evident grading in the forward direction. Finally, when fragmentation occurs during vertically downward flight, dispersal may be expected over a circular area with grading (if any) a function of distance radially outward, and hence just as effective in the backward as in the forward direction.

Depending upon factors which could influence the altitude, timing and energy expended in fragmentation events, the individual areas of dispersal could be completely or only partially superimposed on others, or could occur quite independently at a distance. It seems likely that

with sufficient data a general mathematical expression could be found to describe the distribution in the case of a single event, but for a shower such as Mulga (north), the distribution would involve the integrated result of a whole family of such expressions.

It is not possible to illustrate diagrammatically the full details of distribution of Mulga (north) because of the combination of an overall dimension exceeding 6000 m with interfragmental distances ranging down to less than one metre. Referring to the weight categories of Fig. 6 in descending order, 14 stones of the third category and 44 stones of the fourth category have been omitted from the figure (mostly from the western end); all 55 stones of weights 0.2-1.0 g have been omitted. The general increase in fragment weight to the east is evident in the diagram but is not as marked as might be expected for a relatively narrow ellipse. Multiple fragmentation and the loss of flakes from the surfaces are regarded as the two factors principally responsible for the large overlaps of the weight categories.

The distribution of the component parts of one of the re-assembled stones shows that heavier fragments are not necessarily found further along the line of flight. The composite stone 155/139/140 can be restored to class CP with reasonable confidence. No. 155 weighs more than 150 grams. The balance of the original stone could not have weighed more than 90 g, i.e. if all of the missing material was incorporated with Nos. 139 and 140, and this fell more than 1.8 km further east. The generally tabular shape of No. 155 might provide a partial explanation, but it seems likely that for the later fragmentation events as distinct from earlier ones in more nearly horizontal flight, the fortuitous directions of scatter from the point of burst may have a decisive influence on the points of fall. Note:—Stone No. 140 was belatedly recognised as an impact fragment of No. 139 and so also most likely is No. 141, though it cannot be fitted.

If the distribution of the oriented stones is to be used as an indication of the flight path, the ones most likely to be reliable are the 30 of category CP and 12 of other categories as follows:—CPT Nos. 69, 245, 341, 355, 370, 624, 634, 658, 815; CPS Nos. 260, 759; CPST No. 309. These 12 oriented stones require insignificant amounts of restoration, or in a few cases, have surfaces of lesser crust development attributable to sheltered location. This sample totalling 42 stones is rather inadequate for mathematical treatment, but from visual inspection of a plot of the sites there appeared no reason to change present concepts of the position of the axis of the distribution or the essentially west to east direction of flight. Indeed, for such a small number of stones, the plot has a surprising degree of resemblance to the general distribution.

The general trends of the lateral distribution were determined by dividing the strewnfield into transverse strips 1 km wide, each strip overlapping its neighbours by 0.9 km, and plotting the

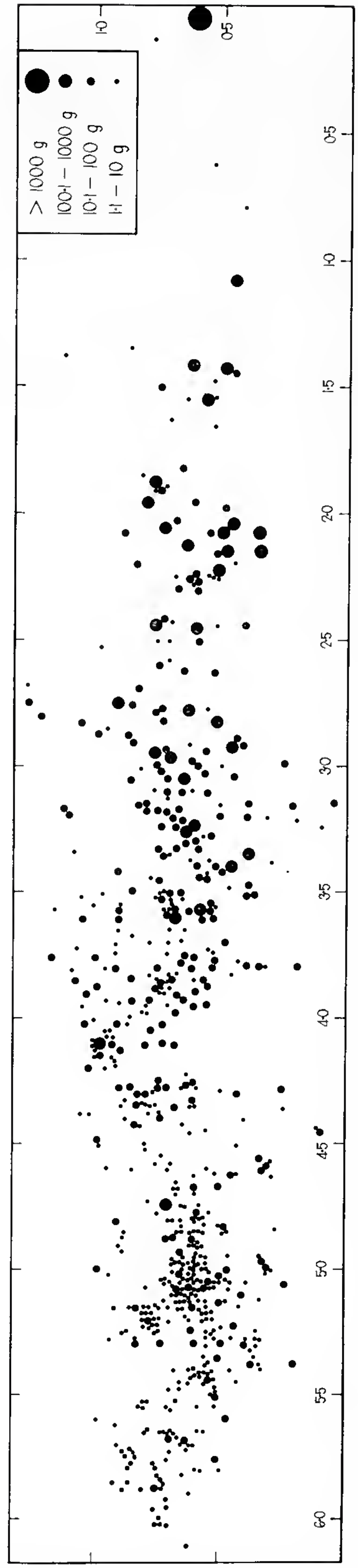

Figure 6.—Diagrammatic representation of the distribution of about 85% of the known pieces of Mulga (north) meteorite (for omissions, see text). Marginal figures along length and width of diagram are kilometres west and north respectively of the datum.

numbers of stones or other statistics at abscissae representing the mid-lines of each strip. The number of stones in each strip is a maximum near the western end of the strewnfield and declines rapidly eastward but with a distinct reversal and secondary maximum at 3.9 km W, where dense crowding may be seen in Fig. 6; the curve has the same general shape if stones/km^2 are plotted but the secondary maximum is less prominent. The weight of material in transverse strips is minimal near the western end and increases eastward, but with a marked inflection centred on about 4.8 km W to attain a maximum at 3.4 km W, and thereafter decreases rapidly; again, the asymmetry is retained on a weight/km^2 basis.

The mean weight of stones in transverse strips is minimal at the western end and increases steadily eastward. It is valid in this case to consider the CP stones separately on the same basis because the removal of some stones —not necessarily the largest—by further fragmentation does not affect the points of fall of other individuals. Stones requiring insignificant restoration may also be included in the sample but all others must be excluded because as complete individuals they would almost certainly have landed elsewhere. The resulting curves

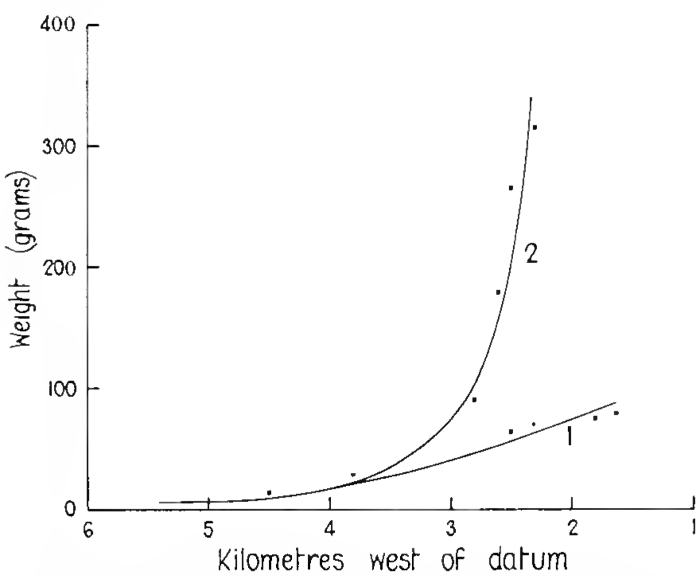

Figure 7.—Mean weights of stones of the Mulga (north) meteorite found in N-S strips 1 km wide, each strip overlapping the neighbouring strips 0.9 kilometre. Curve 1.—All stones; Curve 2.—Completely primary-crusted stones. Only points not falling closely on the curves are shown in the figure.

(Fig. 7) show clearly that there is a real difference between CP stones and the general sample. The curve for CP stones suggests some form of logarithmic relationship between mass and distance, but too much cannot be read into curves of means plotted at mid points. For the same reason, the complexities of the other curves cannot be interpreted as indicating two populations, though that might well be true.

Some limited trials were made with scatter diagrams for individual stones and the best of these appeared to be that of log weight against distance when confined to CP stones (c.f. Frost op.cit.p.228), the "sorting factor" being from inspection of the order of 1.5. The detailed treatment of the distribution has, however, been left to the mathematical specialist.

Acknowledgments

I thank M. K. Quartermaine and T. G. Bateman whose energetic and voluntary search efforts were responsible for more than three quarters of the meteorite finds. I am especially grateful that they returned again to the area with me in 1971 whilst aware of the climatic conditions to be expected and of the severe limitations on water usage.

W.A. School of Mines vehicles were freely used on field work, the three earlier visits being made while the School was a branch of the Mines Department of Western Australia, the two most recent visits since the School became a branch of the Western Australian Institute of Technology.

Appendix

Weights, sites of find, and distribution in collections of the meteorites are given below. Some of the earlier recoveries made by School of Mines personnel have been either donated to or exchanged with the Western Australian Museum, and the later recoveries have been handed over in accordance with the Western Australian Museum Act of 1969 whereby the meteorites are Crown property and are vested in the Museum.

Mulga (south). See Table 3 .The second and sixth items of the table are in the W.A. School of Mines collection, the balance in that of the Western Australian Museum.

Table 3

Weight and locality details of Mulga (south) meteorite

Year of find	W.A.S.M. Catalogue No. or field No. (brackets)	Weight g	Westing km	Northing or Southing (S) km
1963	9584.1	59.5	ca.4.9	ca.0.7 S
,,	9584 2	52.6	ca.4 9	ca.0.7 S
,,	9584.3	16.2	ca.4 9	ca.0 7 S
1964	9738	76 2	ca.4 0	ca.0.55
,,	9739	26 0	ca.4 0	ca.0.55
,,	9740	28 5	ca.3.9	ca.0 1 S
,,	9741	18.9	ca.4.5	ca.0 8 S
..	9742	20.2	ca.4.5	ca.0.8 S
1970	(110)	65.5	2.87	0.86
,,	(179)	112.0	3.94	0.59
,,	(323)	27.9	4.02	0.50
1971	(435)	26.8	5.06	0.41
,,	(449)	38.0	5.65	0.44
,,	(460)	2.9	4.84	0.28
,,	(468)	160.2	4 57	0.21
,,	(488)	32.6	4 25	0.25
,,	(506)	73.5	4.69	0.32
,,	(531)	1.5	2.22	0.40
,,	(532)	13.6	2.22	0.40
,,	(539)	19.4	1.40	0.51
,,	(558)	1.2	3.53	1.15
,,	(595)	1.3	1.55	0.56
,,	(667)	0.3	5 58	0.82
,,	(690)	19.5	5.64	0.69

Billygoat Donga. See Table 4. The main portion of the original stone found by T. and P. Dimer is in the W.A. School of Mines collection (9469), the other two pieces in the Western Australian Museum collection.

Table 4

Weight and locality details of the Billygoat Donga meteorite

Year of find	W.A.S.M. Catalogue No. or field No. (bracketed)	Weight g	Westing km	Northing km
1962	9469	142	ca.3.5	ca.7
1970	(225)	392.4	4.25	0.85
1971	(493)	98.4	4.42	0.69

Mulga (north). Full details of the material set out in the pattern of Table 2 are available on application to the Director, Western Australian Museum, Perth, Western Australia. Ownership follows:—

Smithsonian Institution: Field Nos. 72-84.

W.A. School of Mines: Field Nos. 1-5, 7-10, 12, 14-21, 23-36, 38-43, 45, 46, 48 (part), 49-59.

Western Australian Museum: The balance of the material.

Mulga (west). Field No. 430, weight 169.2 g, found at 5.29 km W and 0.19 km N in 1971 is in the Western Australian Museum collection.

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